Development and Application of a Flow and Transport Model for the Southern Everglades

By

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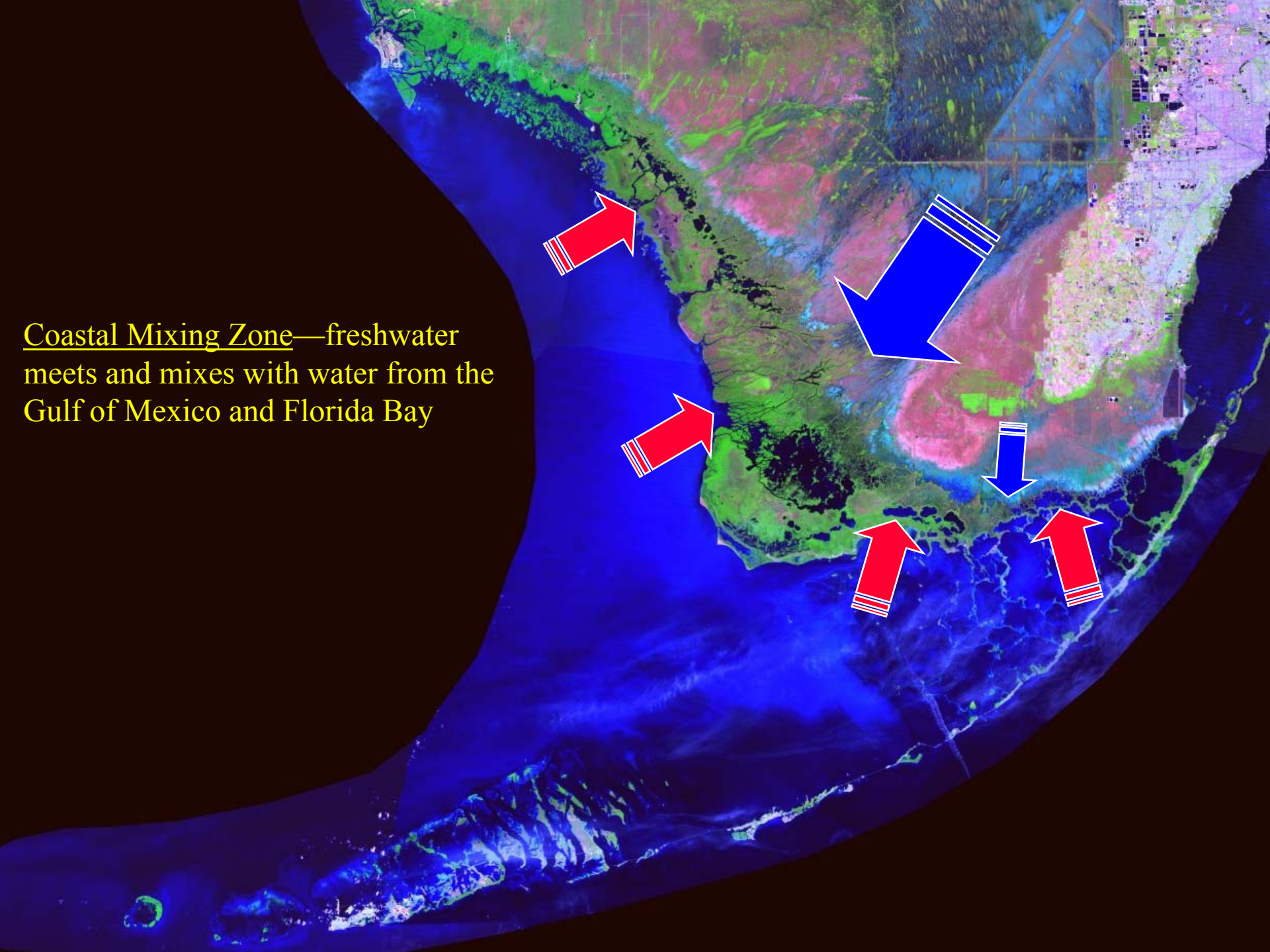
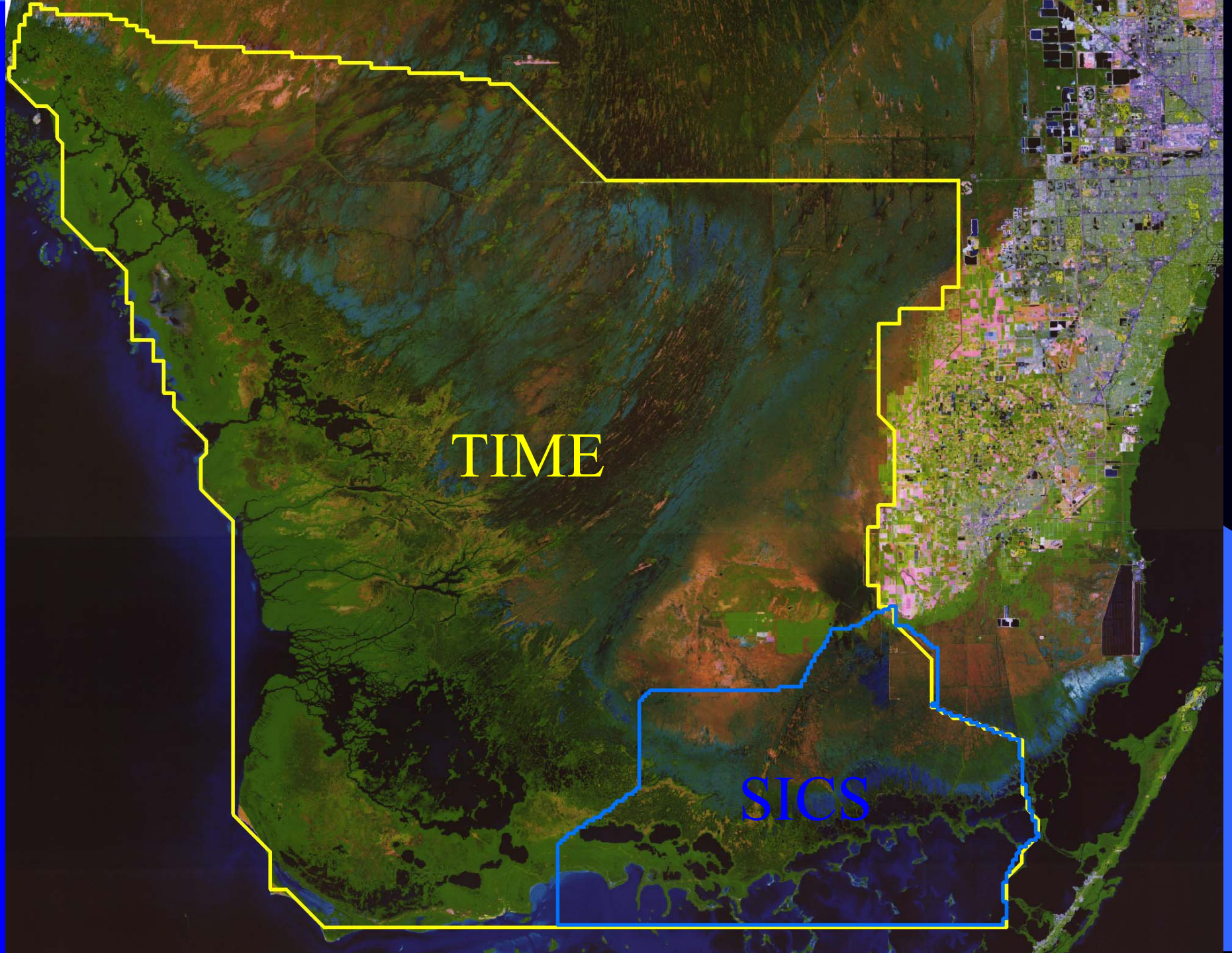
USGS
science for a changing world

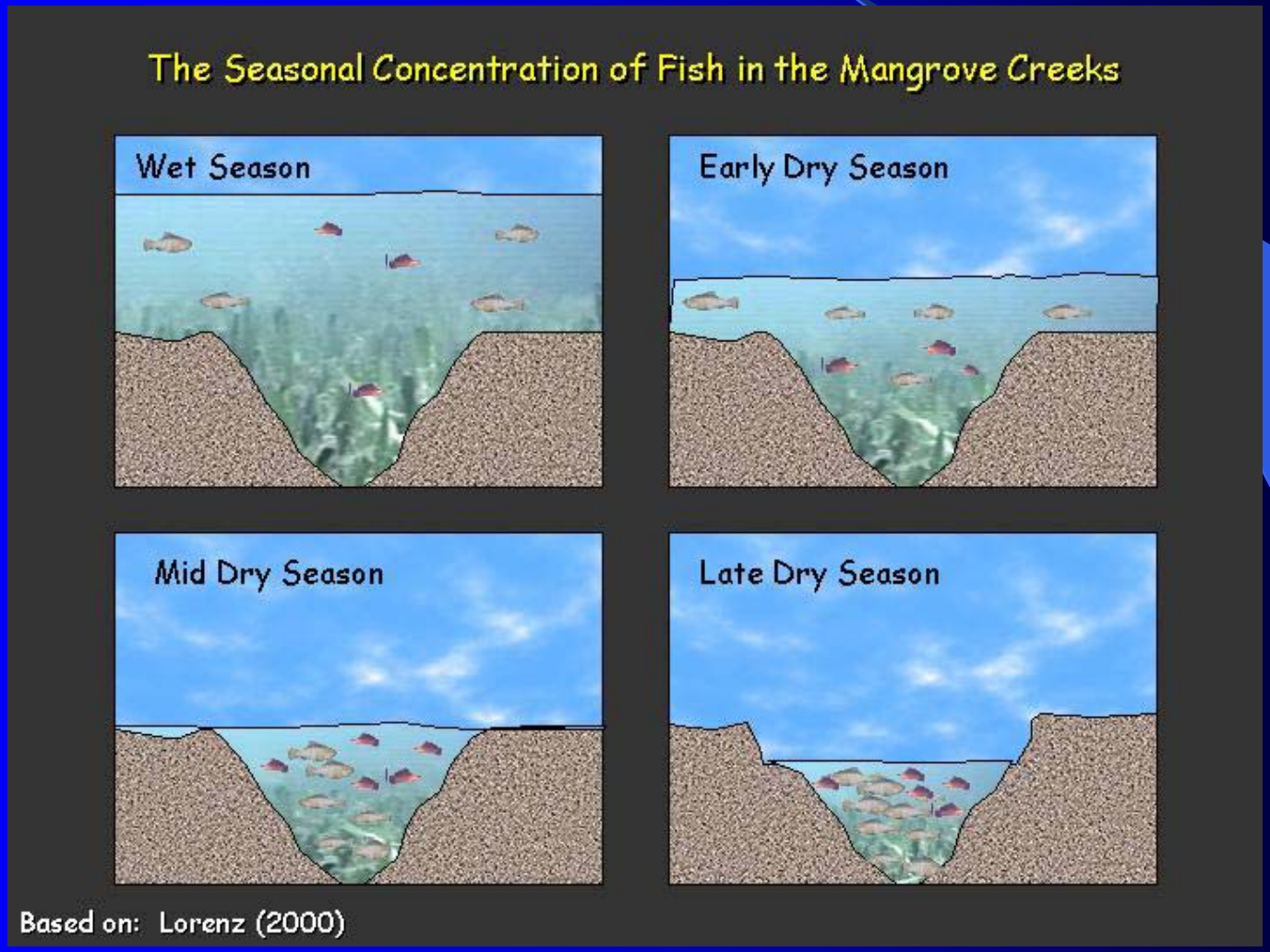

Coastal Mixing Zone—freshwater meets and mixes with water from the Gulf of Mexico and Florida Bay


TIME
SICS

Ecologic Significance of the Southern Everglades

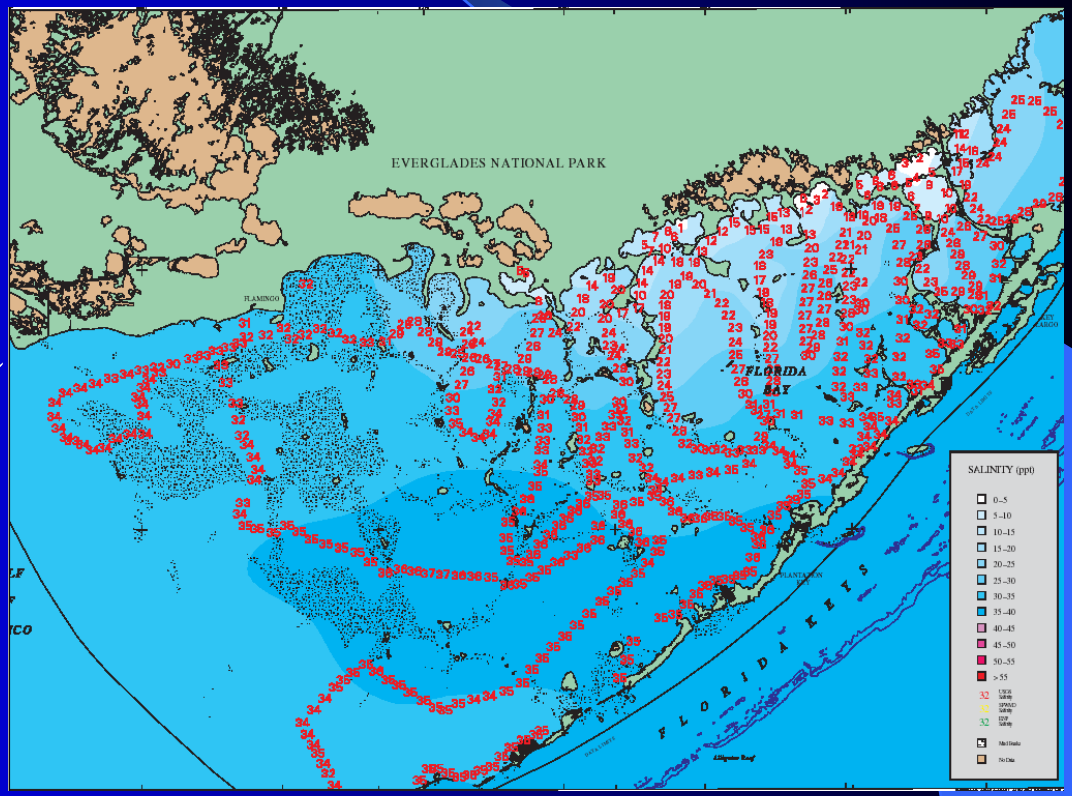
- Crocodiles
- Roseate Spoonbill
- Cape Sable Seaside Sparrow

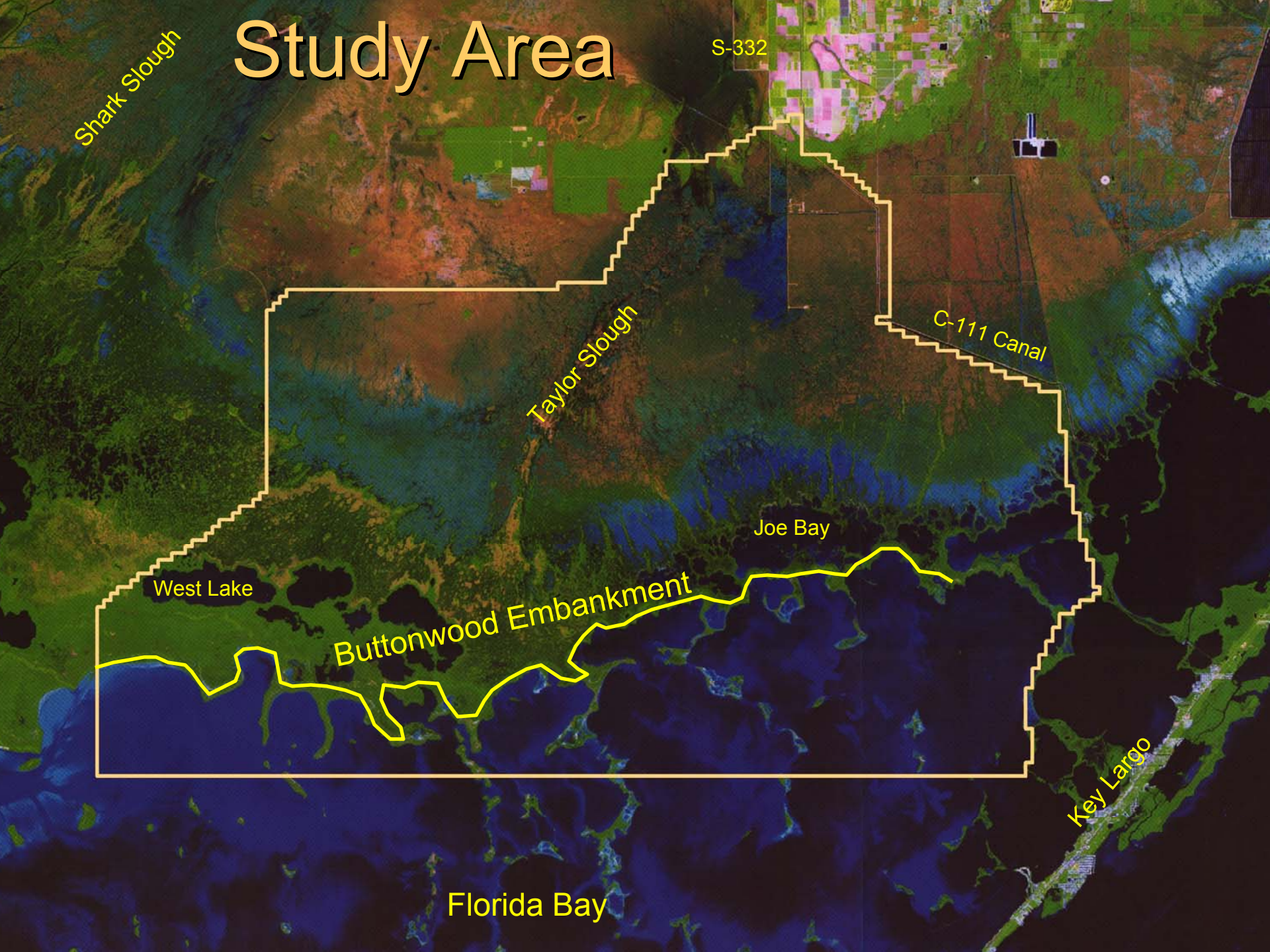
Ecology and Hydrology

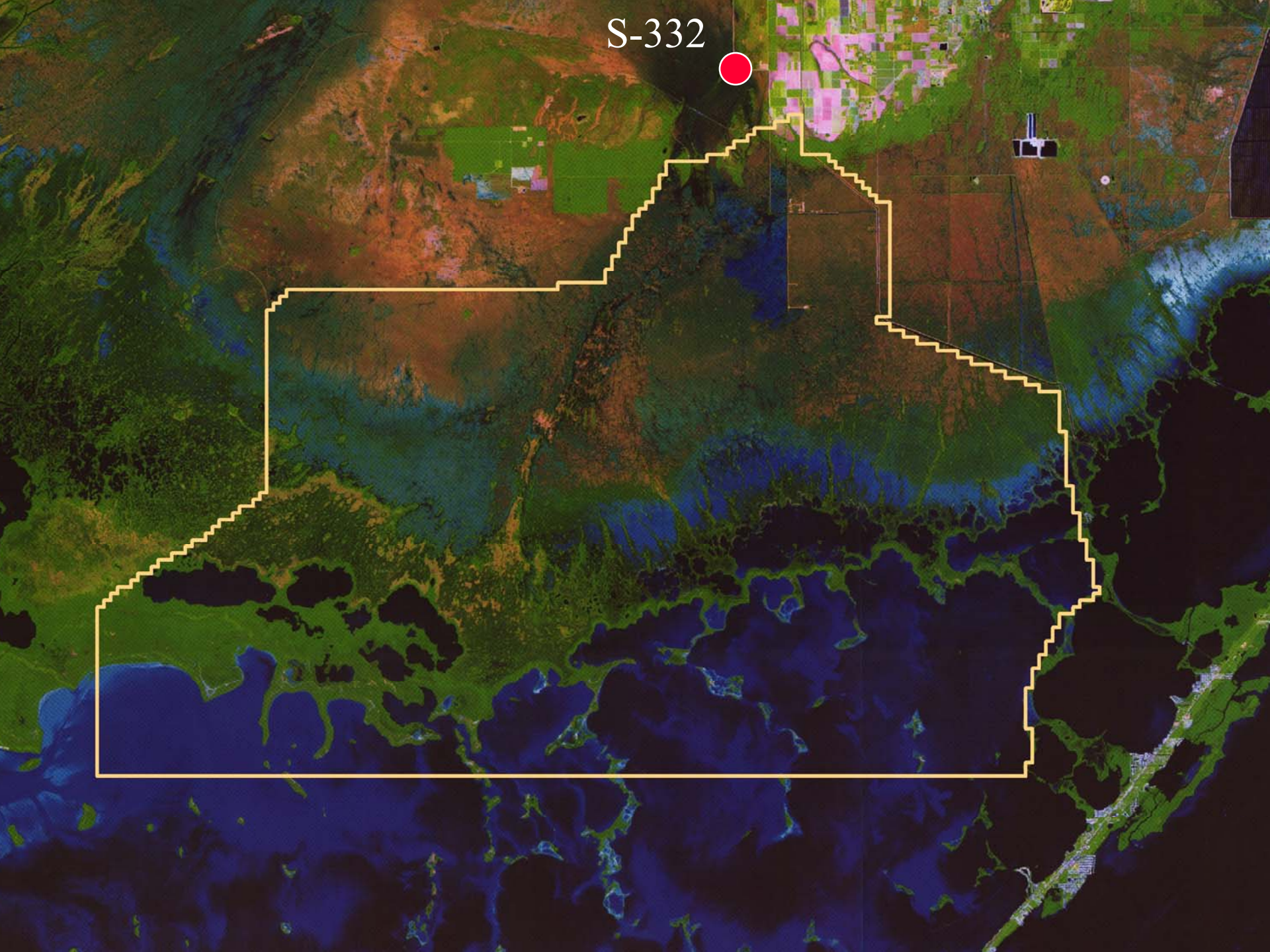


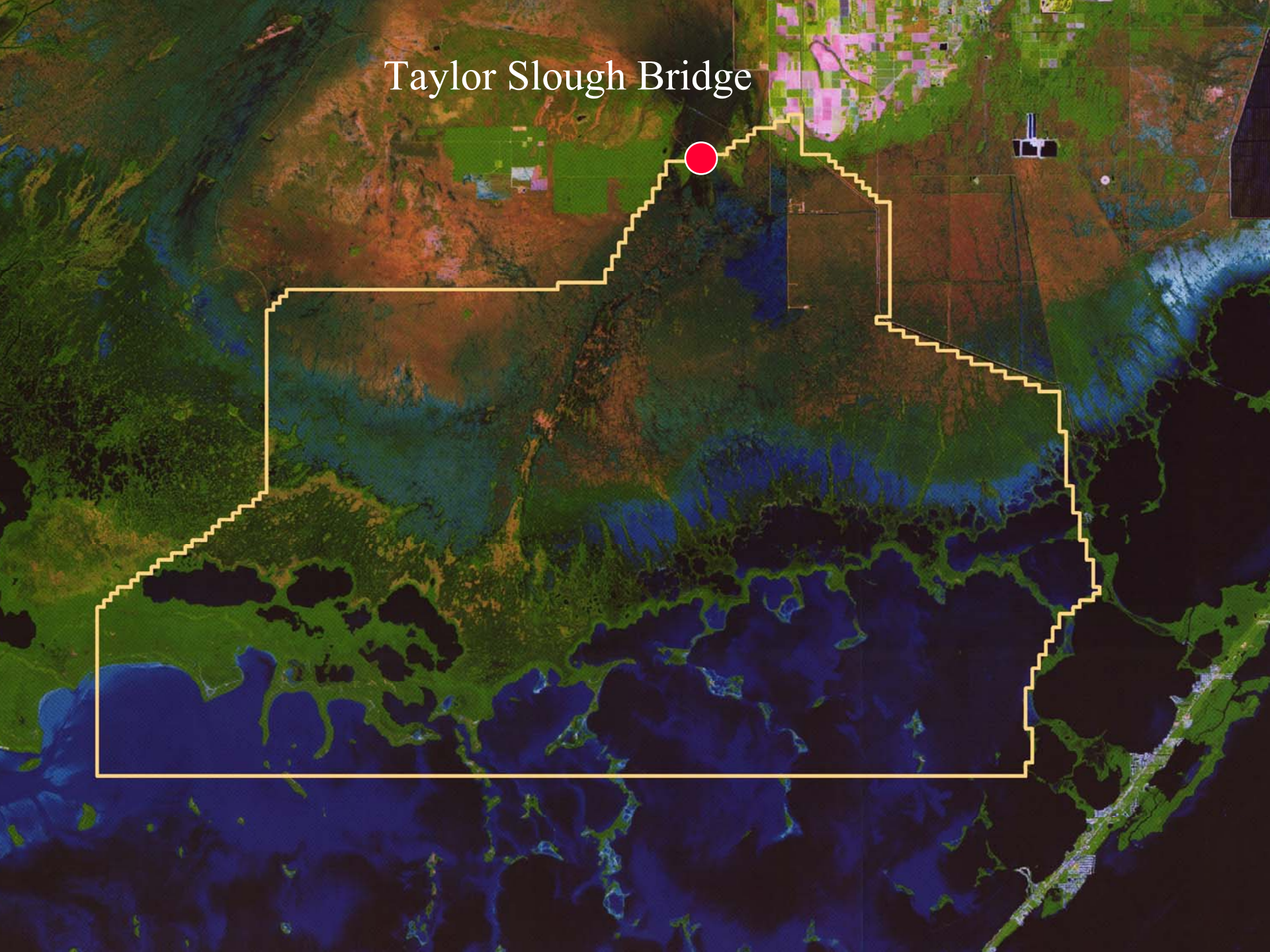
Freshwater Flows to Florida Bay

- Freshwater discharges from coastal wetlands create estuarine conditions in Florida Bay
- Nutrient loading to Florida Bay from coastal wetlands may be responsible for algal blooms and sea grass mortality

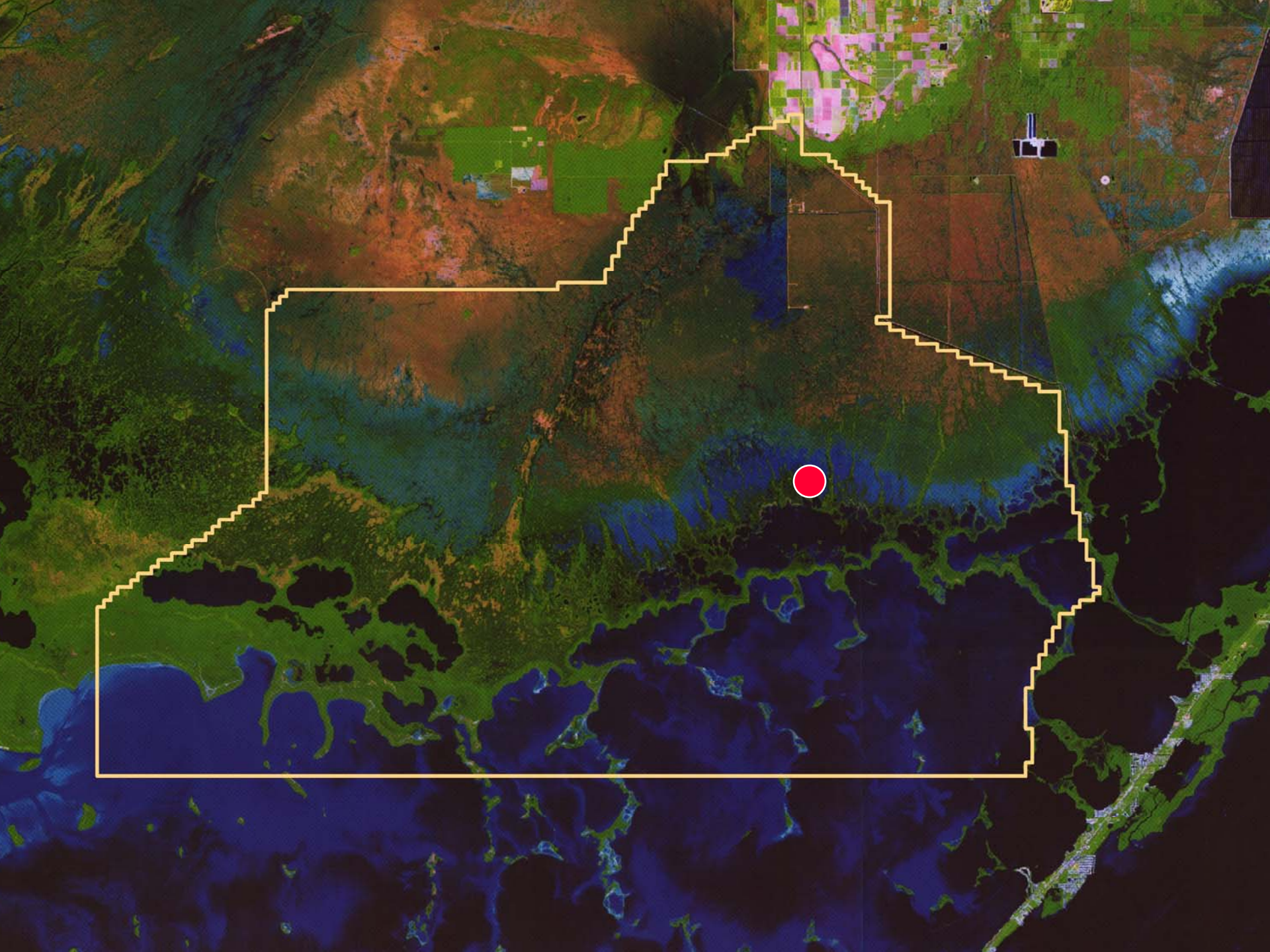


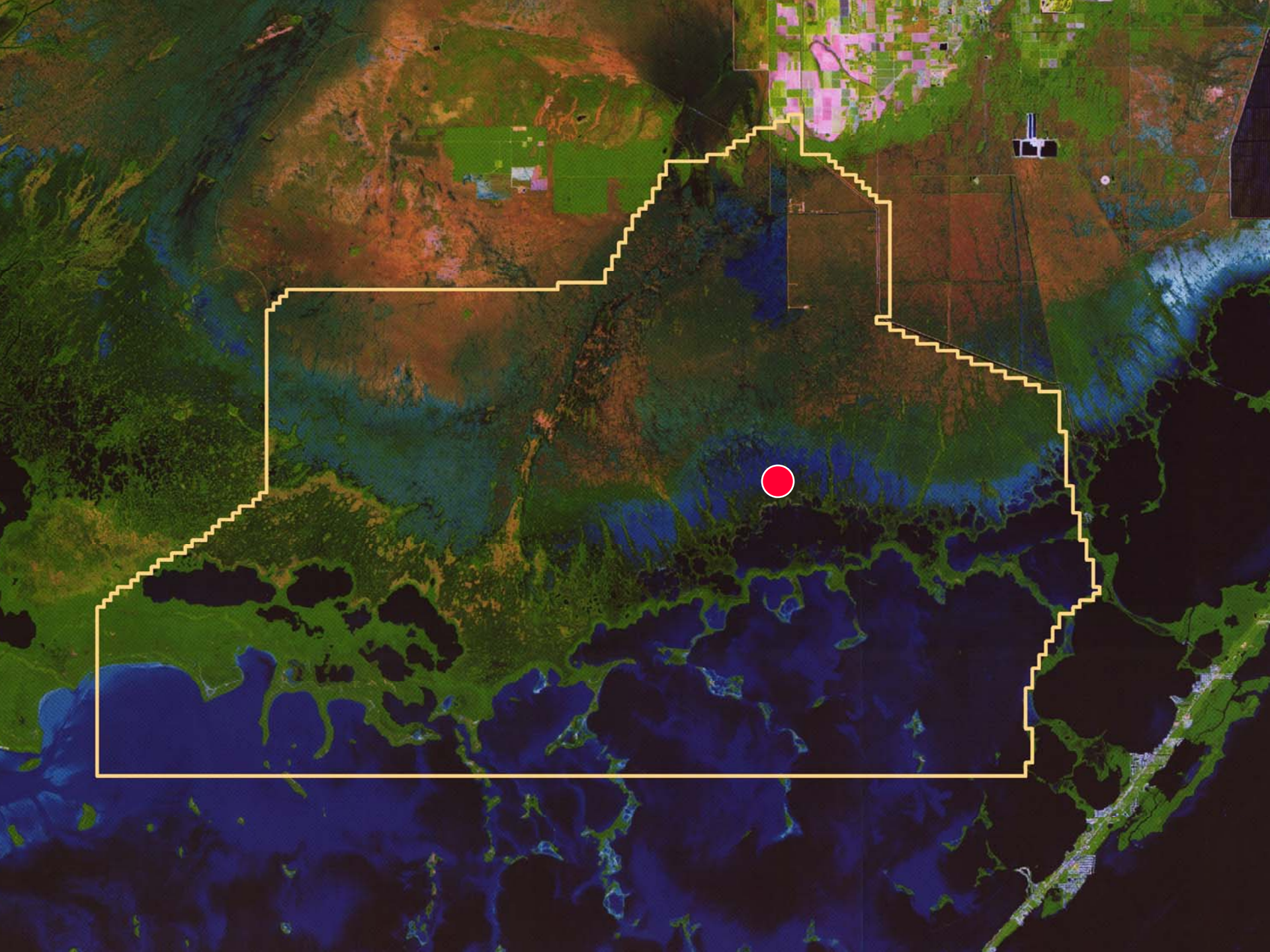

Study Area
Shark Slough
S-332
Taylor Slough
C-111 Canal
Joe Bay
West Lake
Buttonwood Embankment
Key Largo
Florida Bay

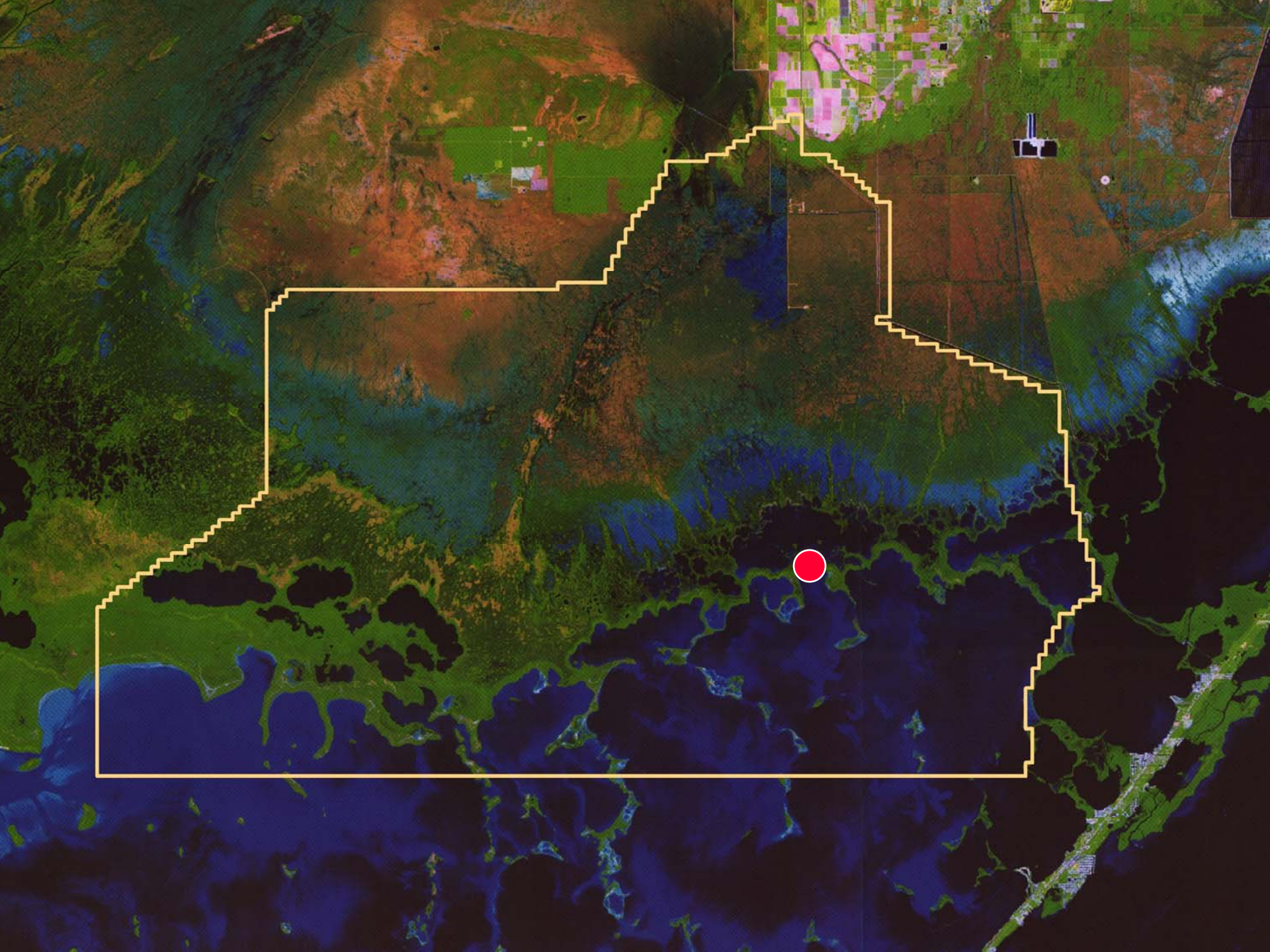

S-332

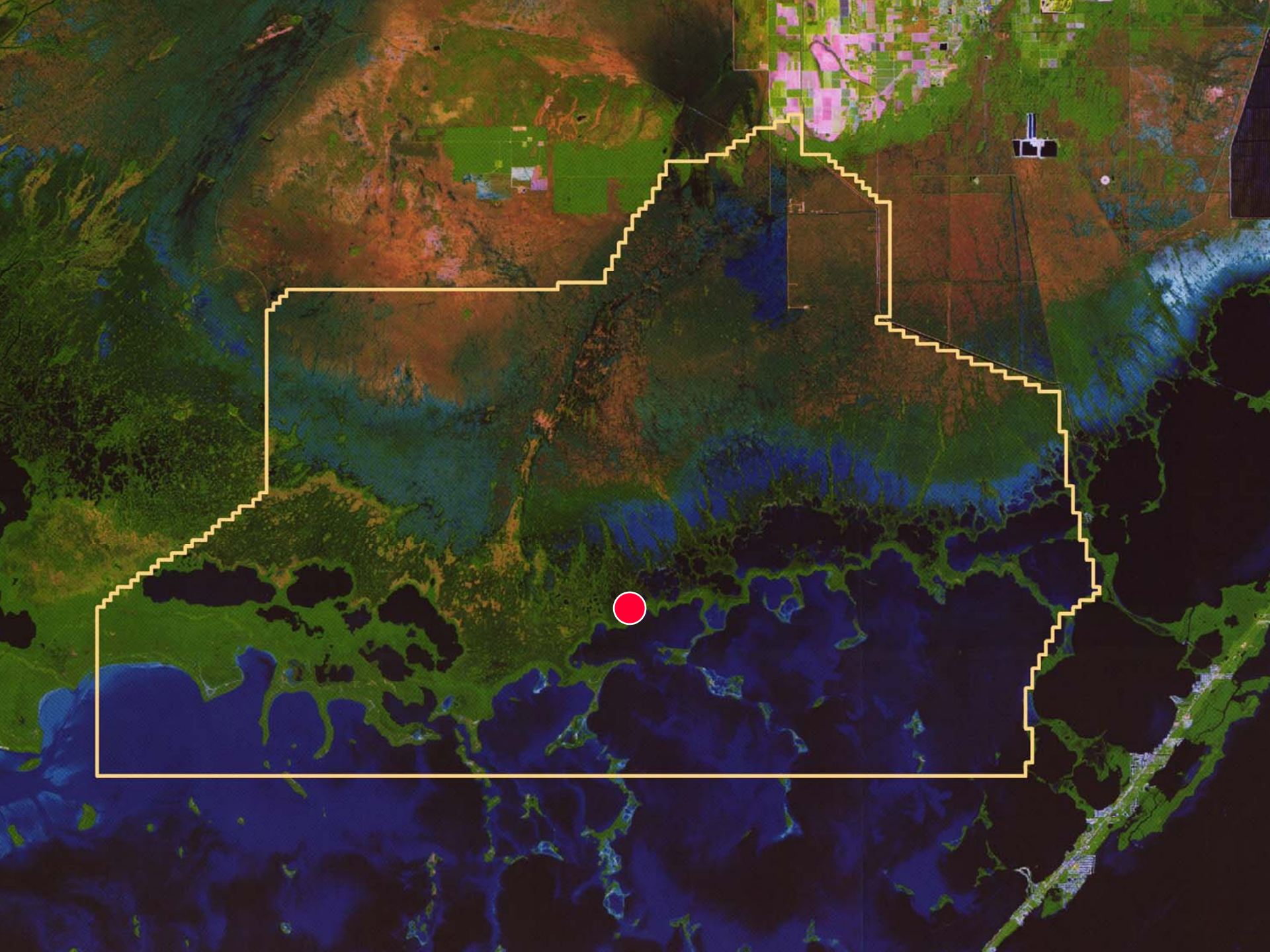

Taylor Slough Bridge


Aerojet Canal







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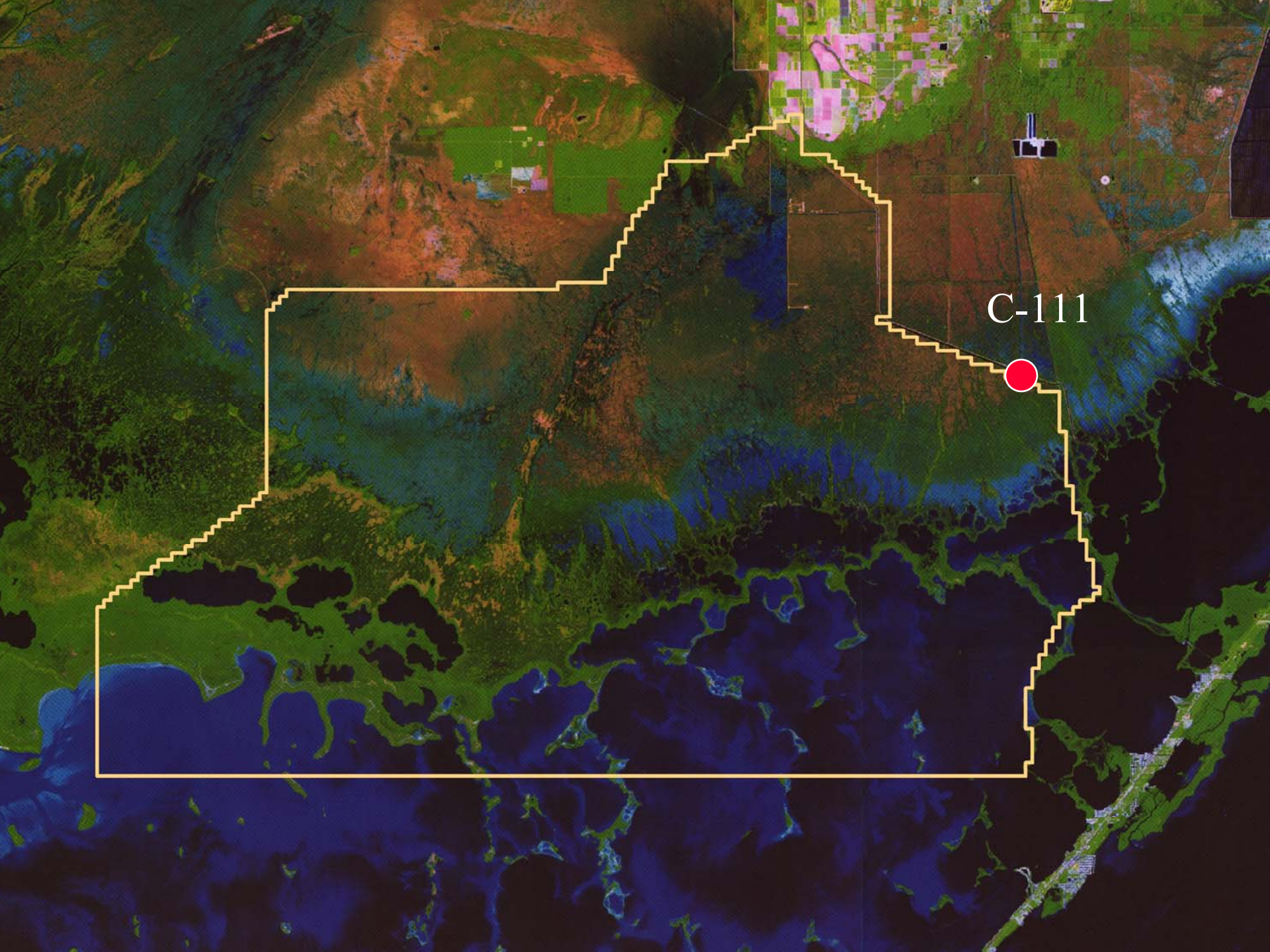
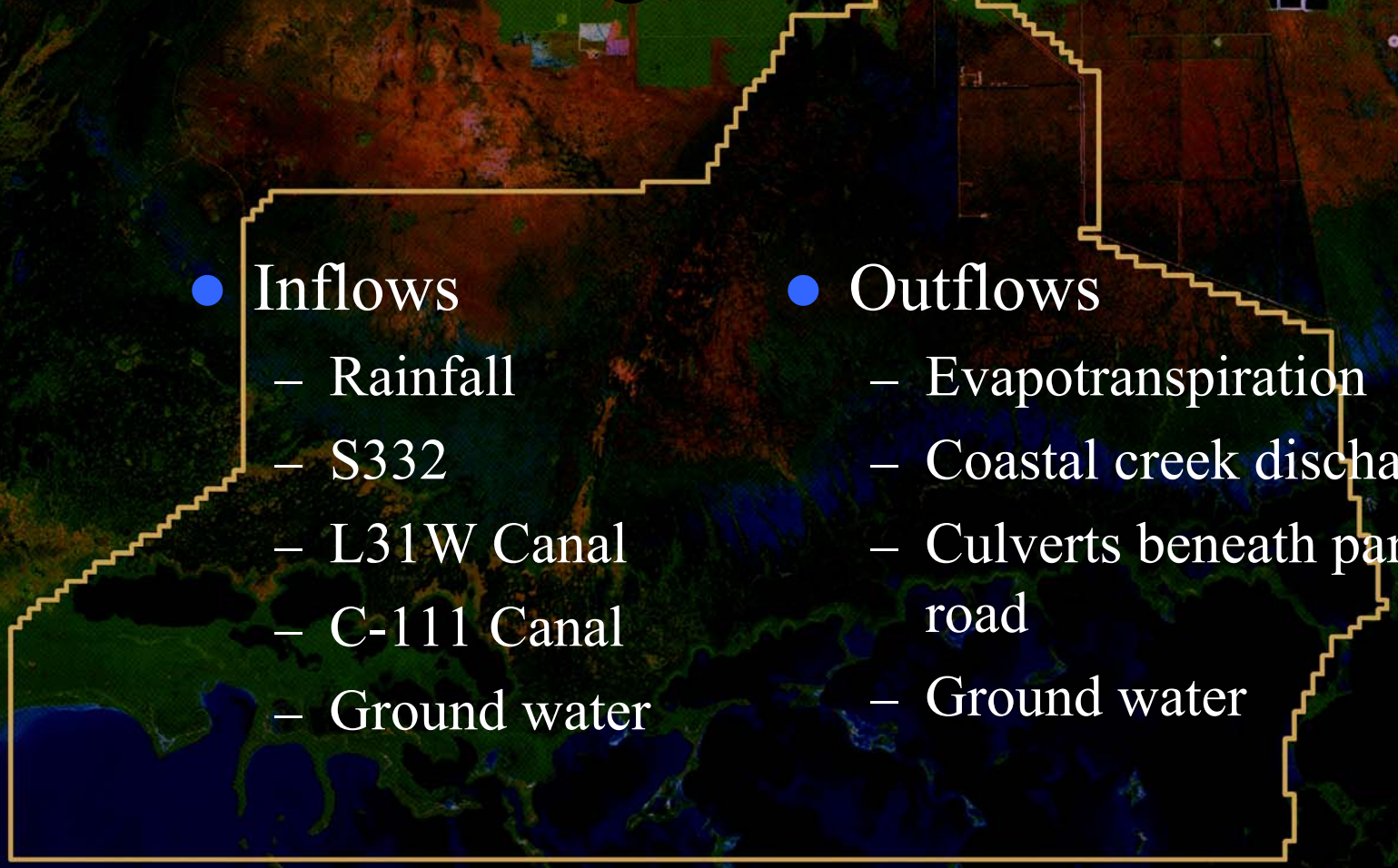
12/ 6/1999


C-111

Water Budget Components

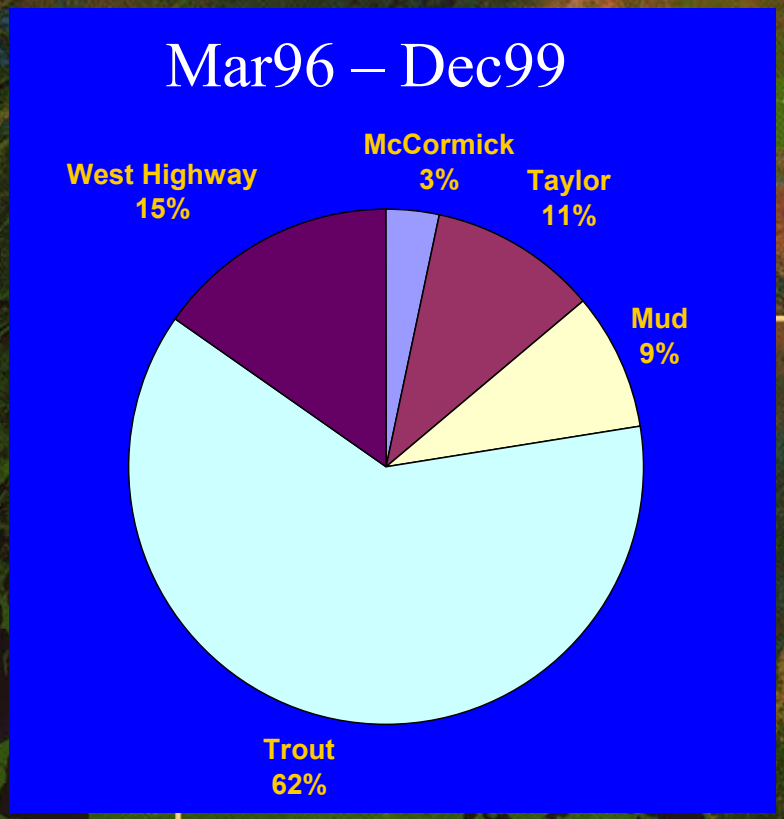


- Inflows
  - Rainfall
  - S332
  - L31W Canal
  - C-111 Canal
  - Ground water
- Outflows
  - Evapotranspiration
  - Coastal creek discharge
  - Culverts beneath park road
  - Ground water

Data Collection Sites

G-1502
NP_TSB
G-613
R158
G-3355
NP_RPL
G-3620
G-3619
R127
G-3621
EVER4
G-1251
TSH
CV9NR
G-3354
EVER7
CT27R
EVER6
G-3353
EVER5
EP1R
EPGW/SW
EP12R
West_Highway
CP
Upstream_Taylor
Trout
Mud
Taylor
McCormick

Coastal Creek Discharge



West Highway
East Highway
Oregon
Trout
Stillwater
Mud
Shell
Taylor
East Creek
McCormick
Alligator

Numerical Modeling Objectives

- Synthesize a wide range of hydrologic data into a numerical framework
- Develop insight into the behavior of the system by determining the relative importance of hydrologic processes and parameters
- Develop a predictive understanding of wetland hydroperiods, coastal interface salinities, and freshwater flows to Florida Bay

Surface Water/Groundwater Interactions

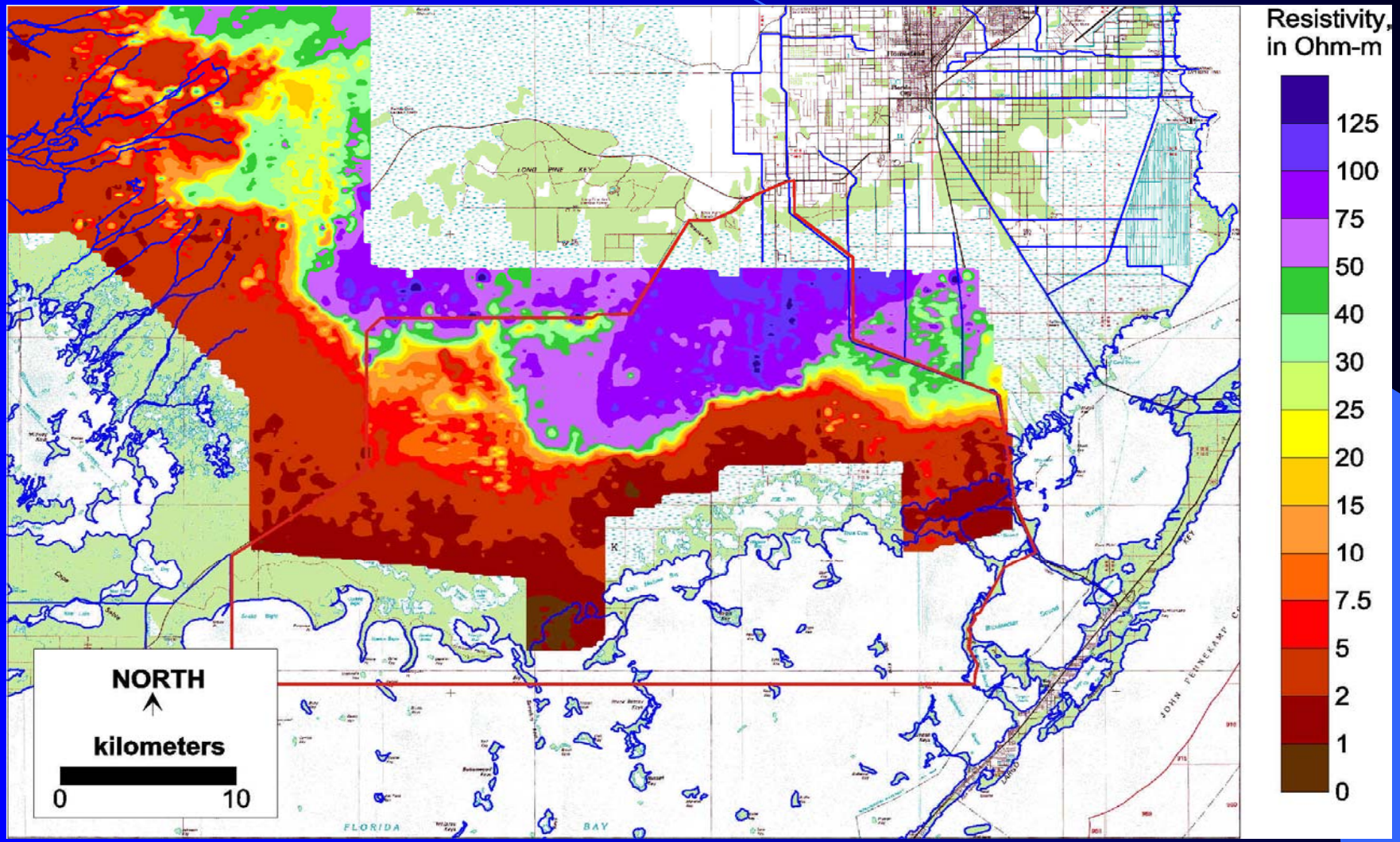
- "We expect that water fluxes across the surface-subsurface are small in this constantly inundated low-relief system, so we neglect the contribution of infiltration and groundwater recharge to the surface water mass balance…"

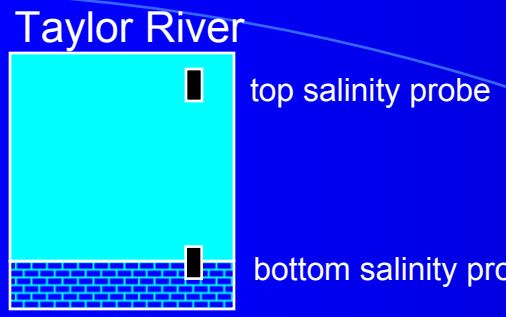
  -Bolster and Saiers, Journal of Hydrology, 2002

- "… a calculation for November 1997 indicated that ground-water discharge might have been as large as 3 cm/day [in Taylor Slough], or approximately an order of magnitude higher than evapotranspiration"

  -Harvey, J.W. et al., U.S. Geological Survey Program on the South Florida Ecosystem: 2000 Proceedings.

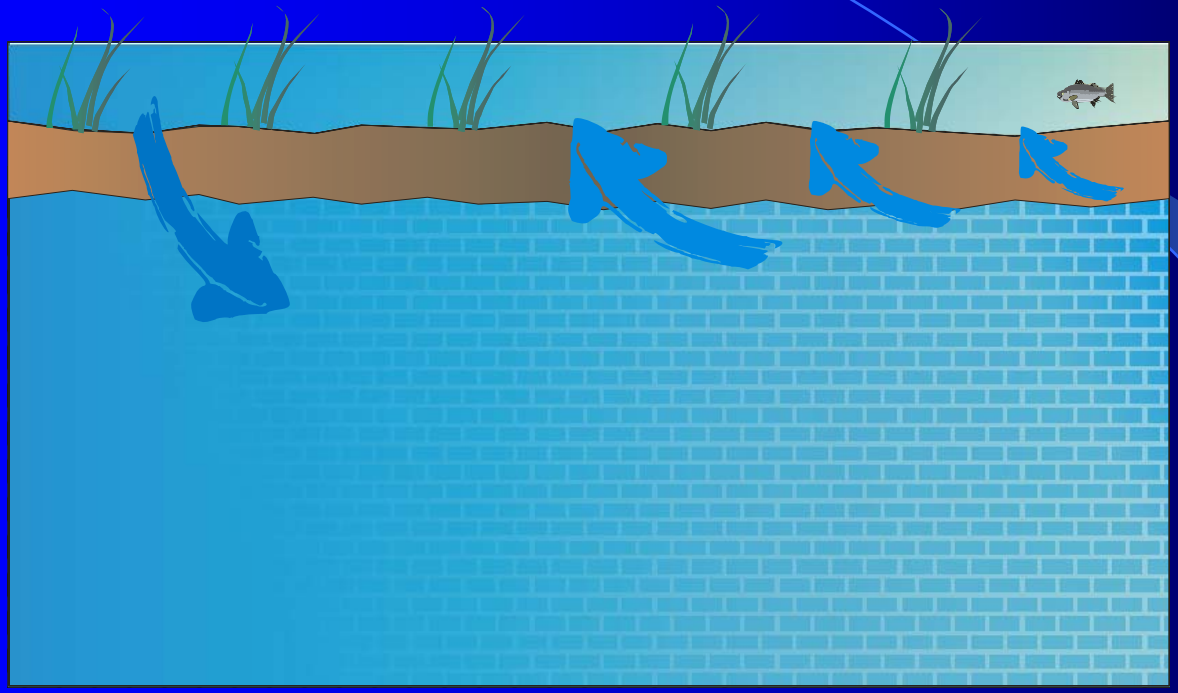
Airborne Resistivity Survey





Evidence for SW/GW Interactions

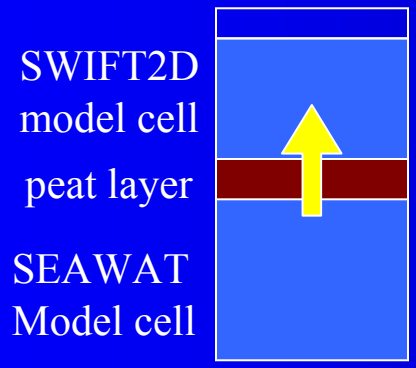
INTEGRATED CODE



SWIFT2D

FTLOADDS

SEAWAT



Variable-density form of Darcy's law

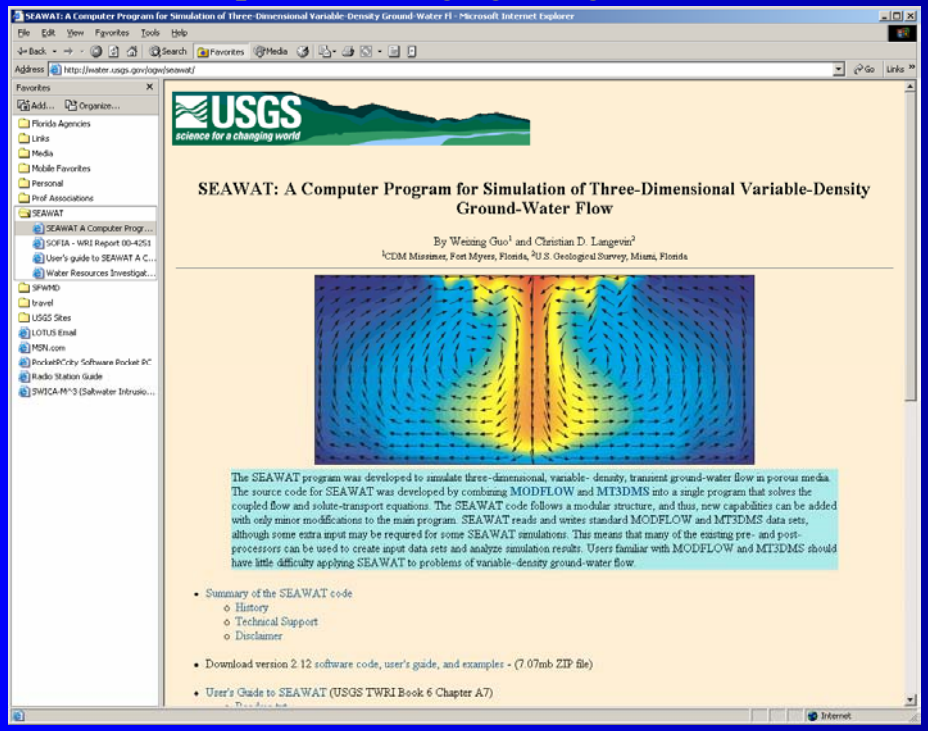
$$Q = \frac{KA}{L}\left[h_{f,SW} - h_{f,GW} + \frac{\bar{\rho} - \rho_f}{\rho_f}\left(Z_{SW} - Z_{GW}\right)\right]$$

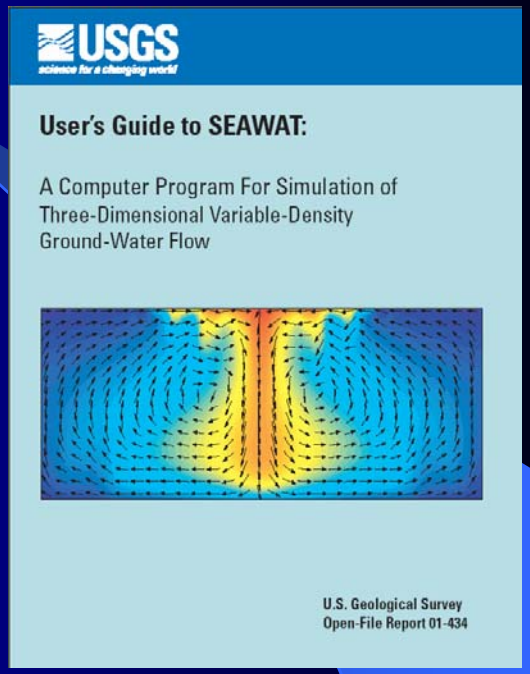
SEAWAT

•Guo, W., and Langevin, C.D., 2002, User's guide to SEAWAT: A computer program for simulation of three-dimensional variable-density ground-water flow: U.S. Geological Survey Techniques of Water Resources Investigations Book 6, Chapter A7, 79 p.

•Langevin, C.D., Shoemaker, W.B., and Guo, W., 2003, MODFLOW-2000, The U.S. Geological Survey Modular Ground-Water Model—Documentation of the SEAWAT version for variable-density flow (VDF Process) and integrated transport using MT3DMS (IMT Process). U.S. Geological Survey Open-File Report 03-426.

http://water.usgs.gov/ogw/seawat





$$\frac{\partial z_1}{\partial t}+\frac{\partial (HU)}{\partial x}+\frac{\partial (HV)}{\partial y}=0$$

$$\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial x}+V\frac{\partial U}{\partial y}-fV=$$

$$-g\frac{\partial z_1}{\partial x}-\frac{g}{2}\frac{H}{\rho}\frac{\partial \rho}{\partial x}-RU+\frac{C_d\rho_a W^2\sin\theta}{\rho H}+k_x\left[\frac{\partial^2 U}{\partial x^2}+\frac{\partial^2 U}{\partial y^2}\right]$$

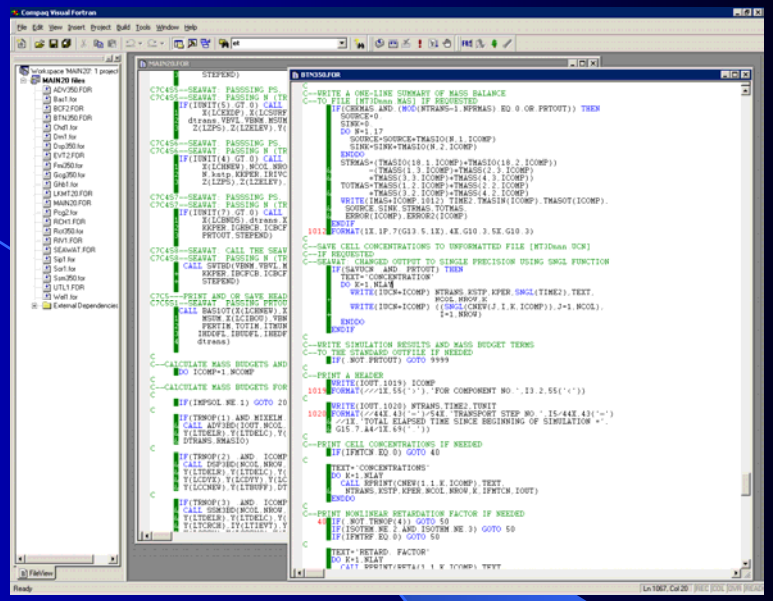
$$\frac{\partial V}{\partial t}+U\frac{\partial V}{\partial x}+V\frac{\partial V}{\partial y}-fU=$$

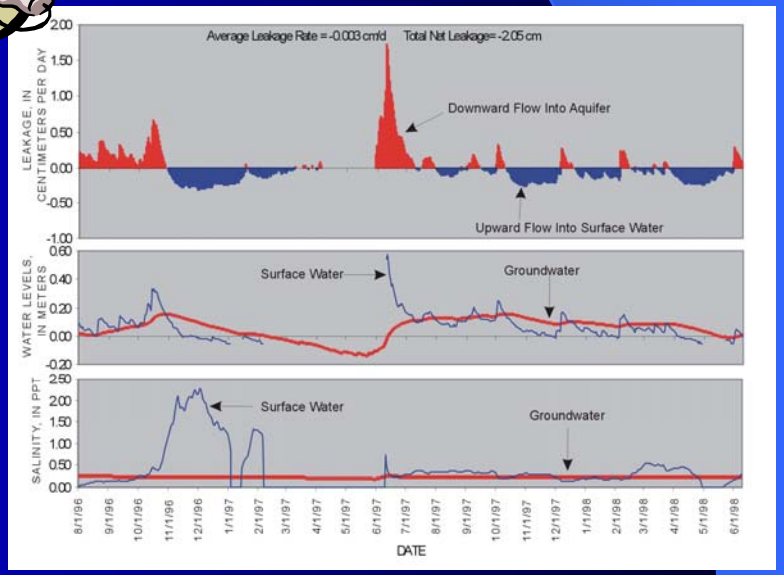
$$-g\frac{\partial z_1}{\partial y}-\frac{g}{2}\frac{H}{\rho}\frac{\partial \rho}{\partial y}-RV+\frac{C_d\rho_a W^2\cos\theta}{\rho H}+k_y\left[\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}\right]$$

$$\frac{\partial (HS)}{\partial t}+\frac{\partial (HUS)}{\partial x}+\frac{\partial (HVS)}{\partial y}+\frac{\partial}{\partial x}\left(HD_x\frac{\partial S}{\partial x}\right)+\frac{\partial}{\partial y}\left(HD_y\frac{\partial S}{\partial y}\right)+G=0$$

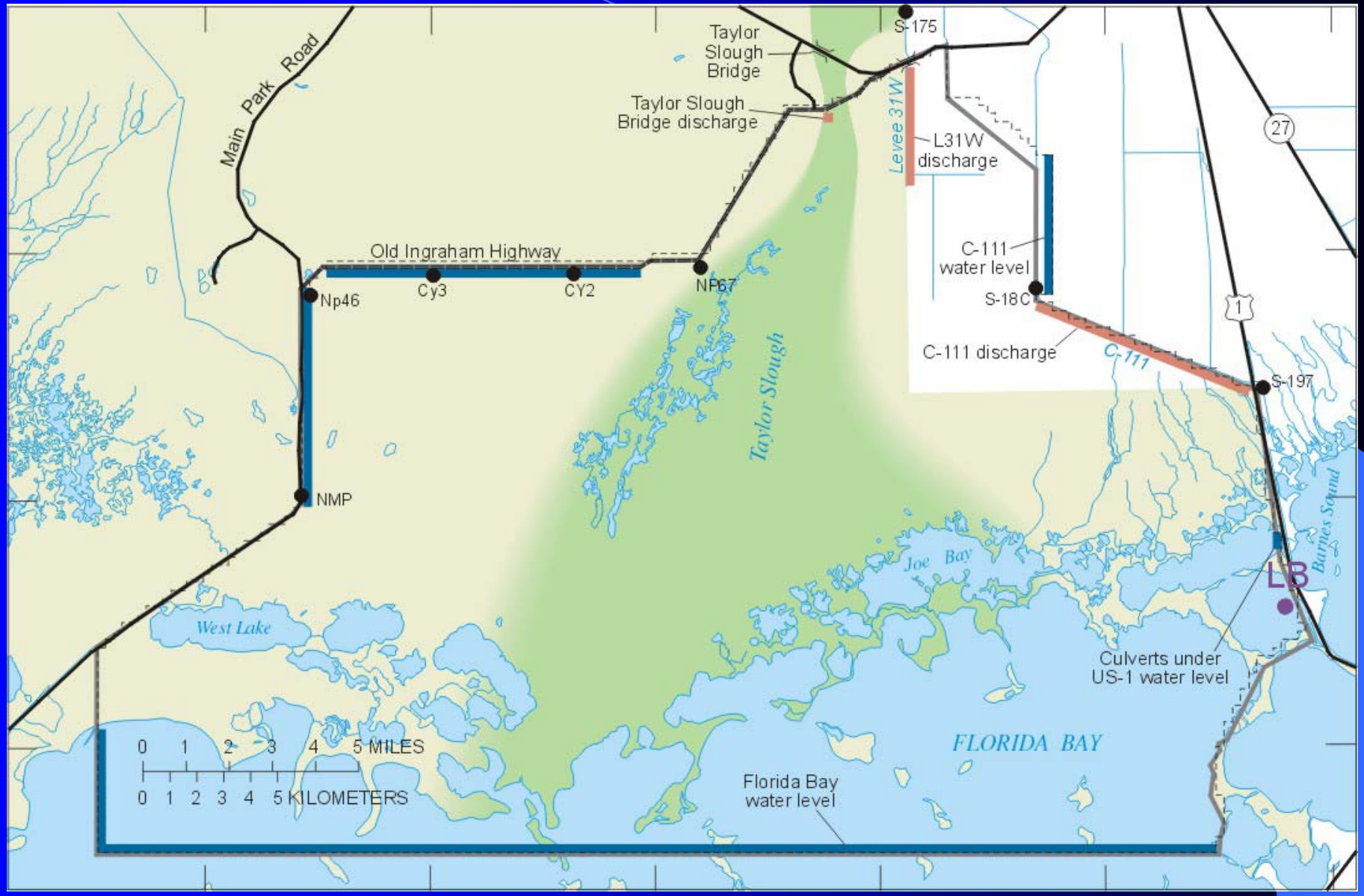
$$\frac{\partial}{\partial x}\left[\rho K_{fx}\left(\frac{\partial h_f}{\partial x}\right)\right]+\frac{\partial}{\partial y}\left[\rho K_{fy}\left(\frac{\partial h_f}{\partial y}\right)\right]+\frac{\partial}{\partial z}\left[\rho K_{fz}\left(\frac{\partial h_f}{\partial z}+\frac{\rho-\rho_f}{\rho_f}\right)\right]=\rho S_f\frac{\partial h_f}{\partial t}+n\frac{\partial \rho}{\partial C}\frac{dC}{\partial t}-\rho q_s$$

$$\frac{\partial C}{\partial t}=\nabla(D\nabla C)-\nabla\cdot(\vec{v}C)-\frac{q_s}{n}C_s$$

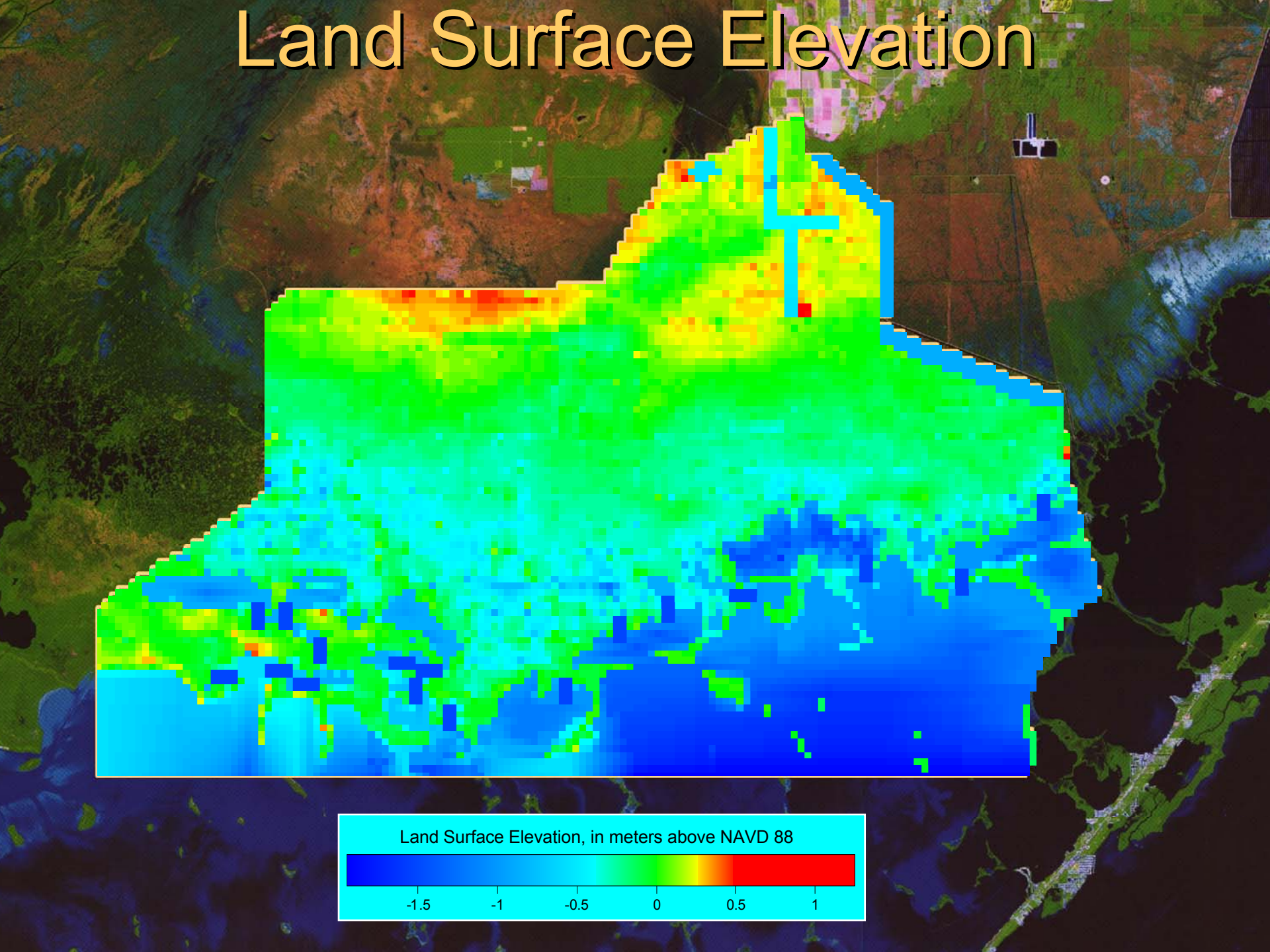




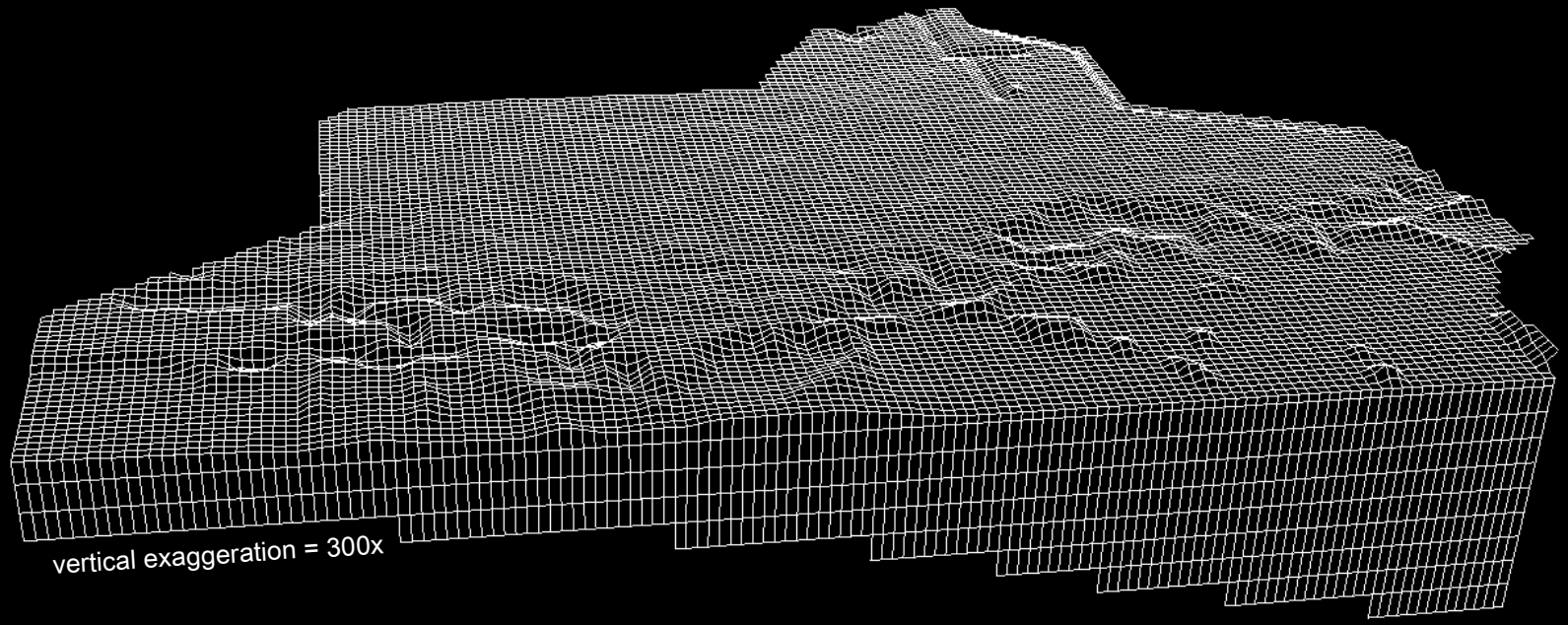
Model Boundaries



Land Surface Elevation



Model Description



FORCING FUNCTIONS

HYDROLOGIC PARAMETERS

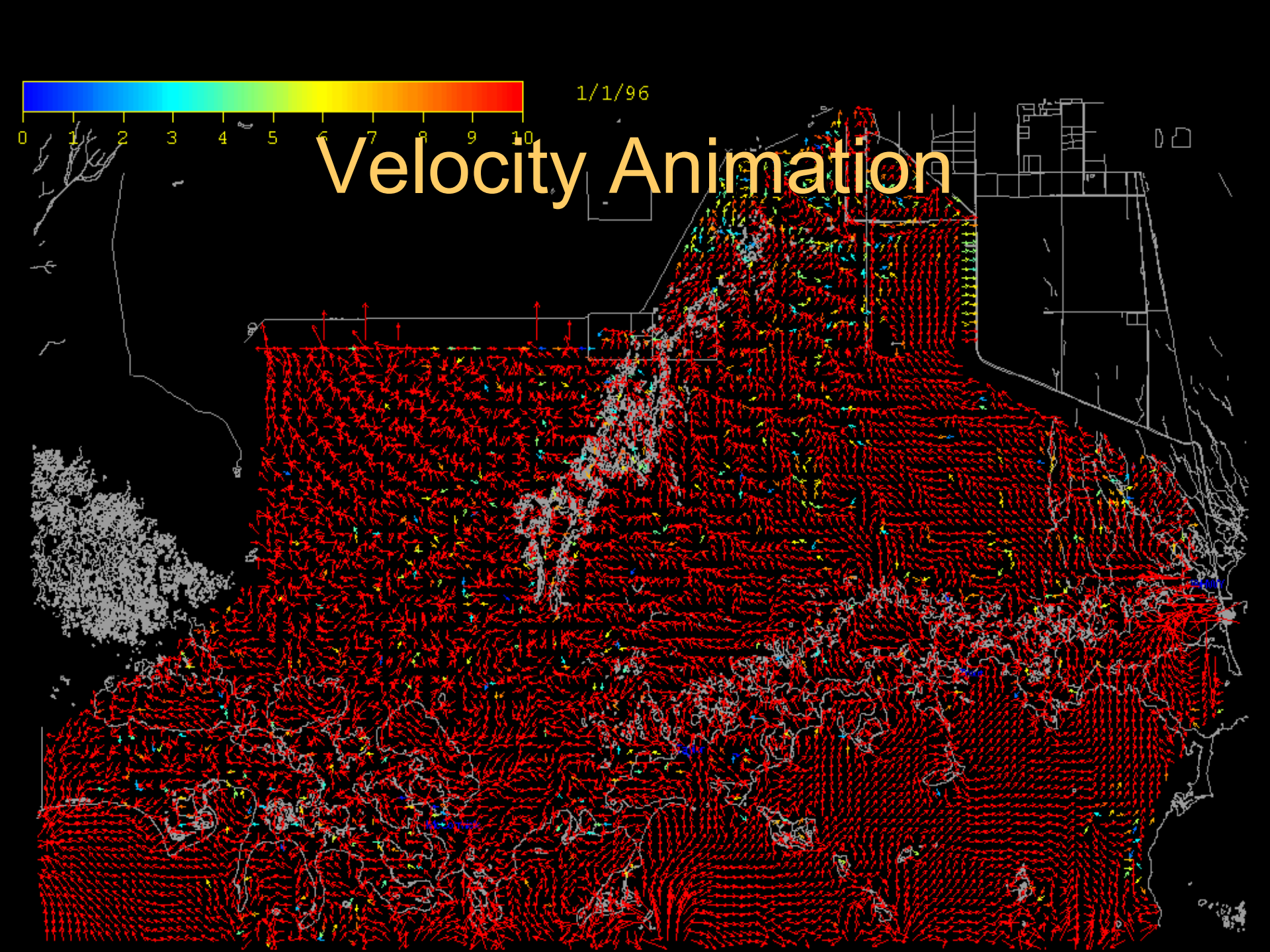
HYDROLOGIC PROCESSES

2D variable-density overland flow and transport

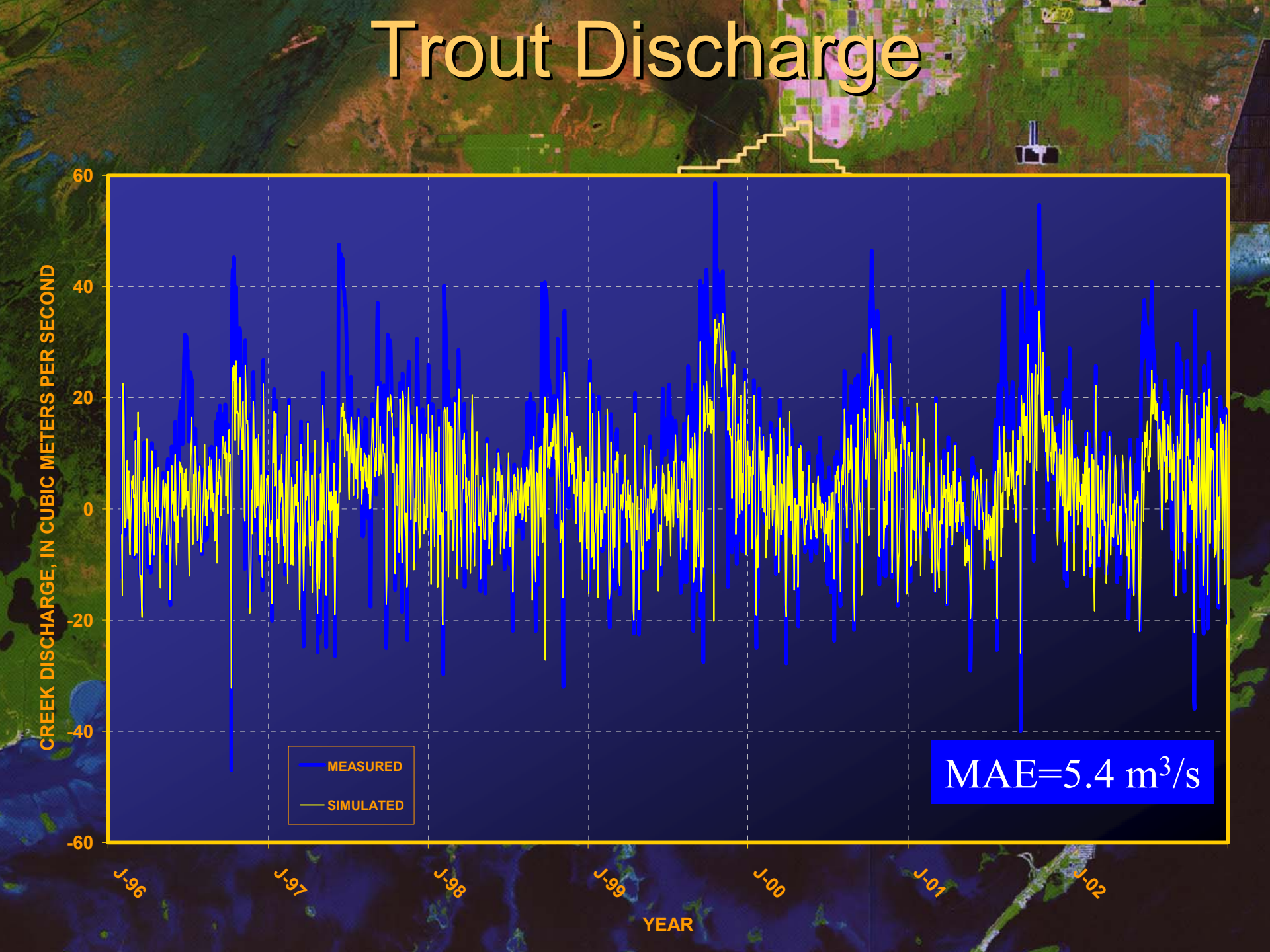
3D variable-density groundwater flow and transport

Surface water/groundwater exchange with transport

PREDICTIONS

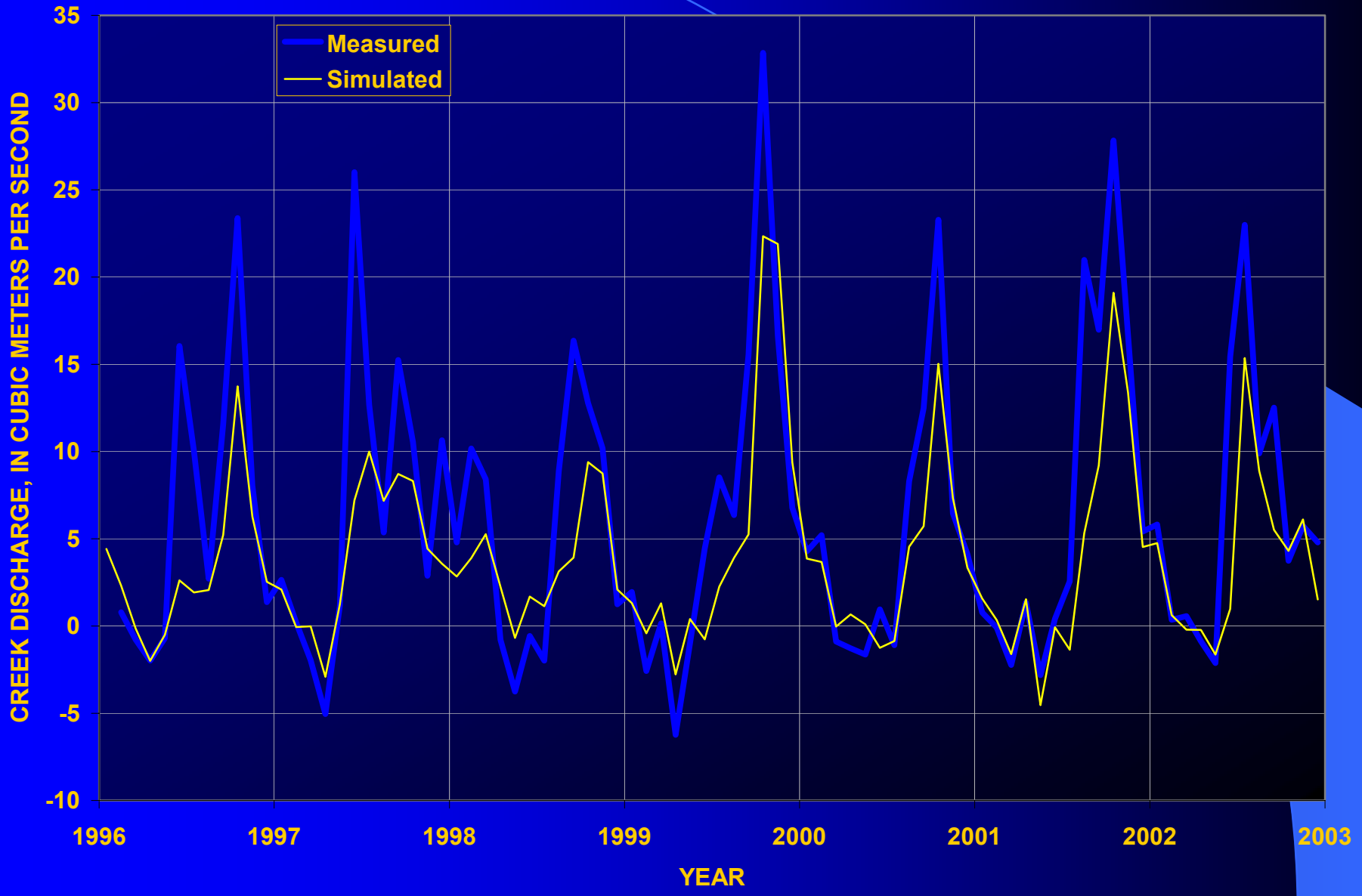

0 1 2 3 4 5 6 7 8 9 10
1/1/96
Velocity Animation

Trout Discharge

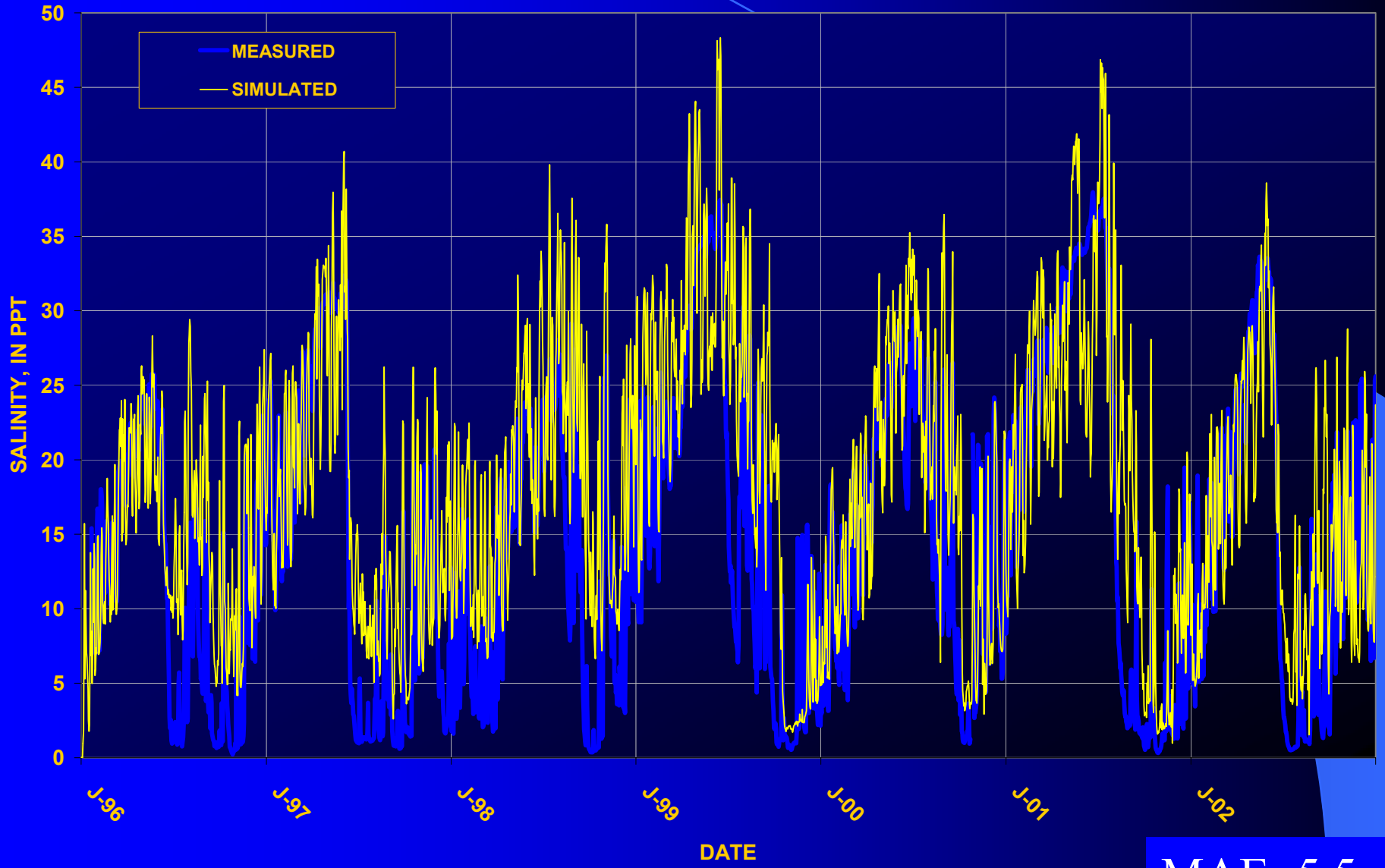


Trout Discharge

Average Monthly Values

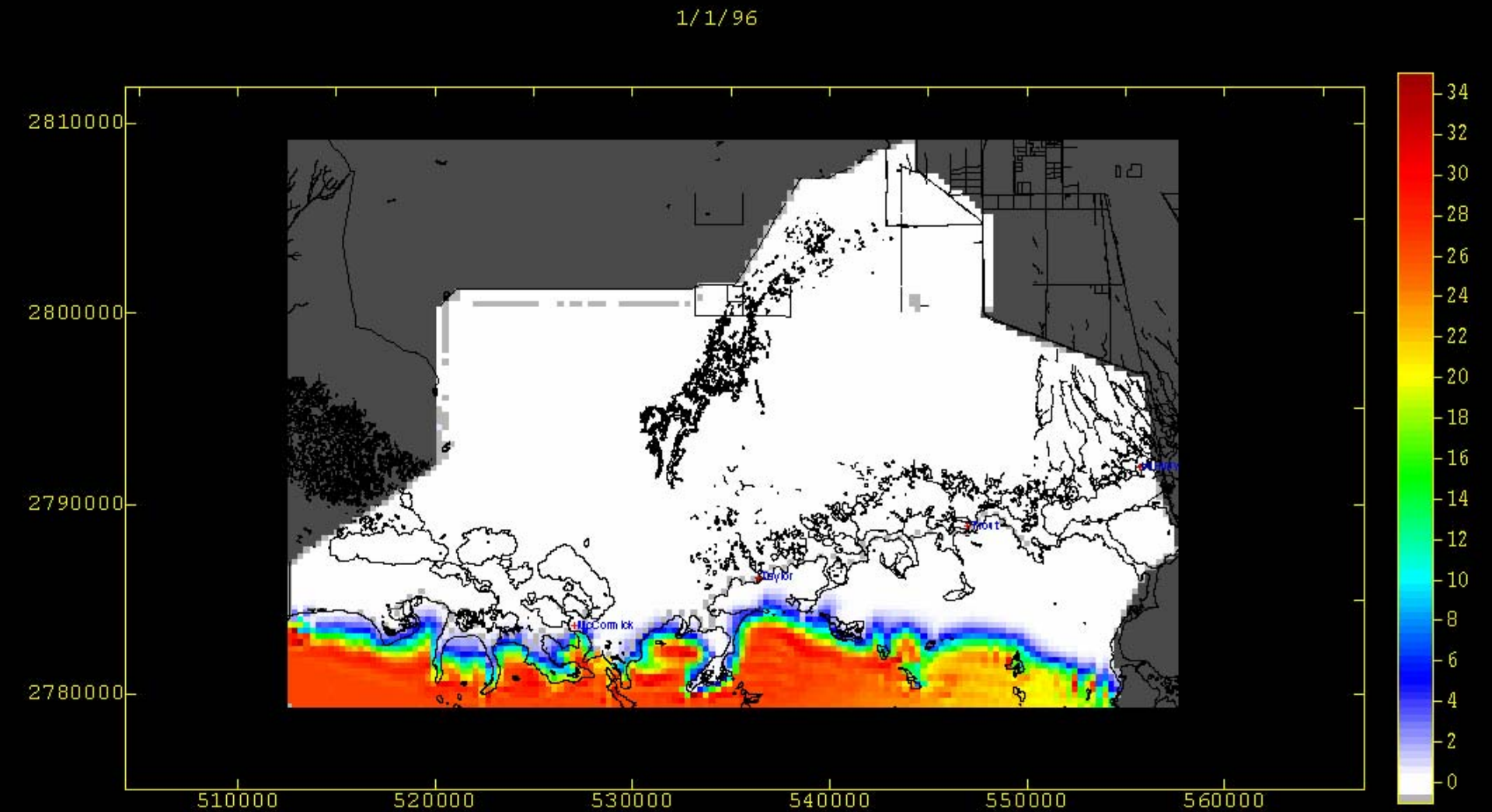


Trout Salinity

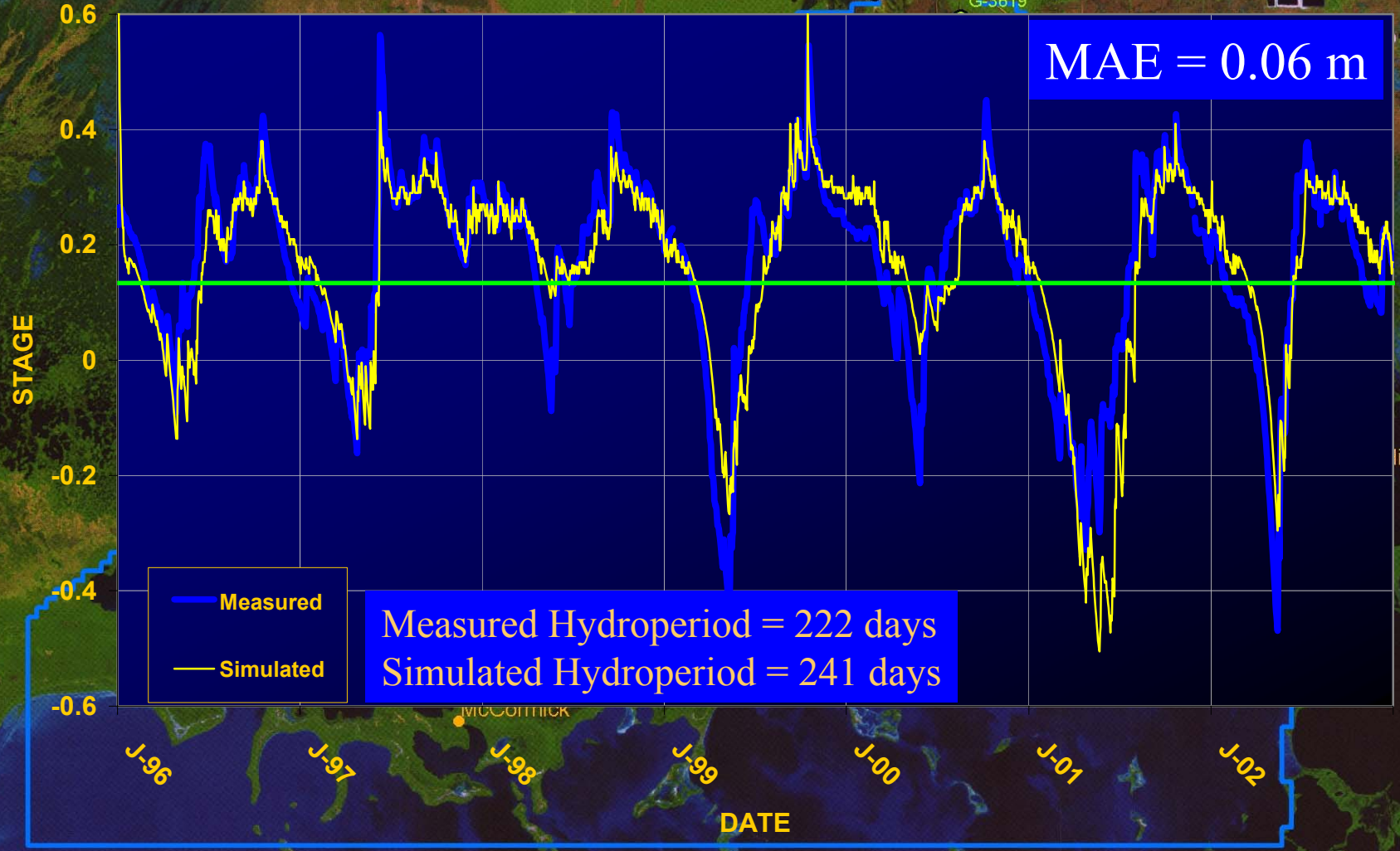


MAE=5.5 ppt

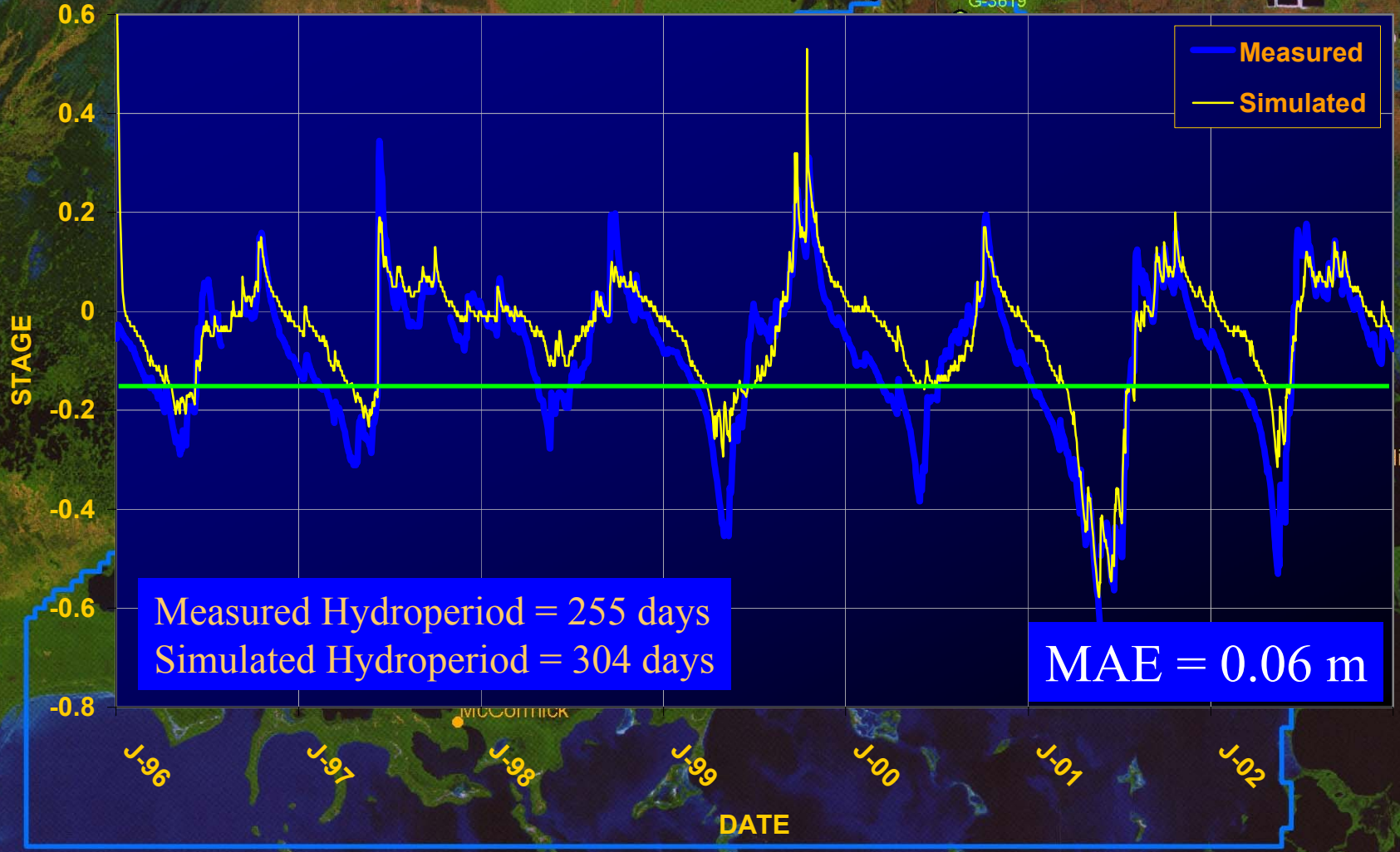
Salinity Animation



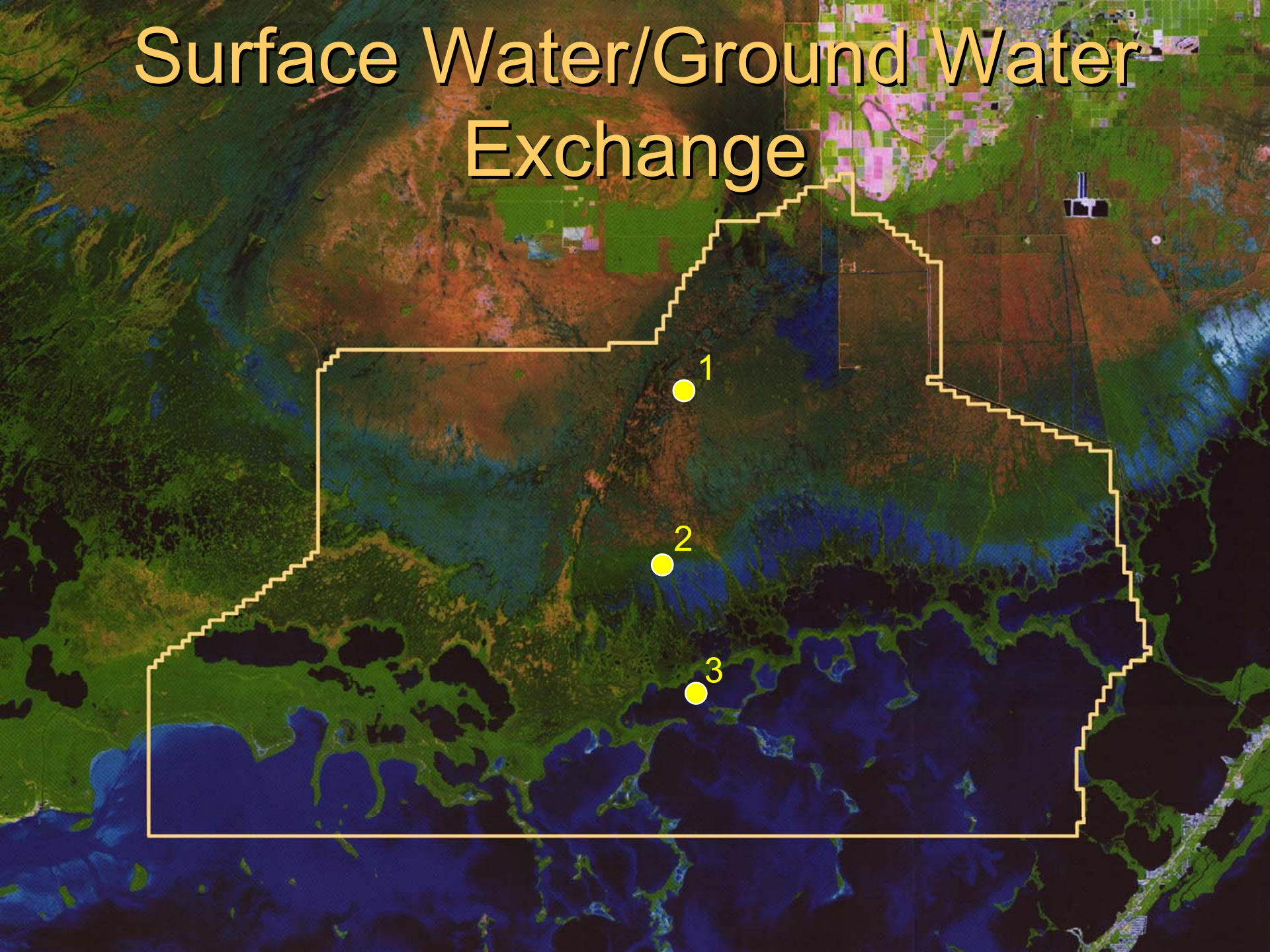
Wetland Stage at TSH

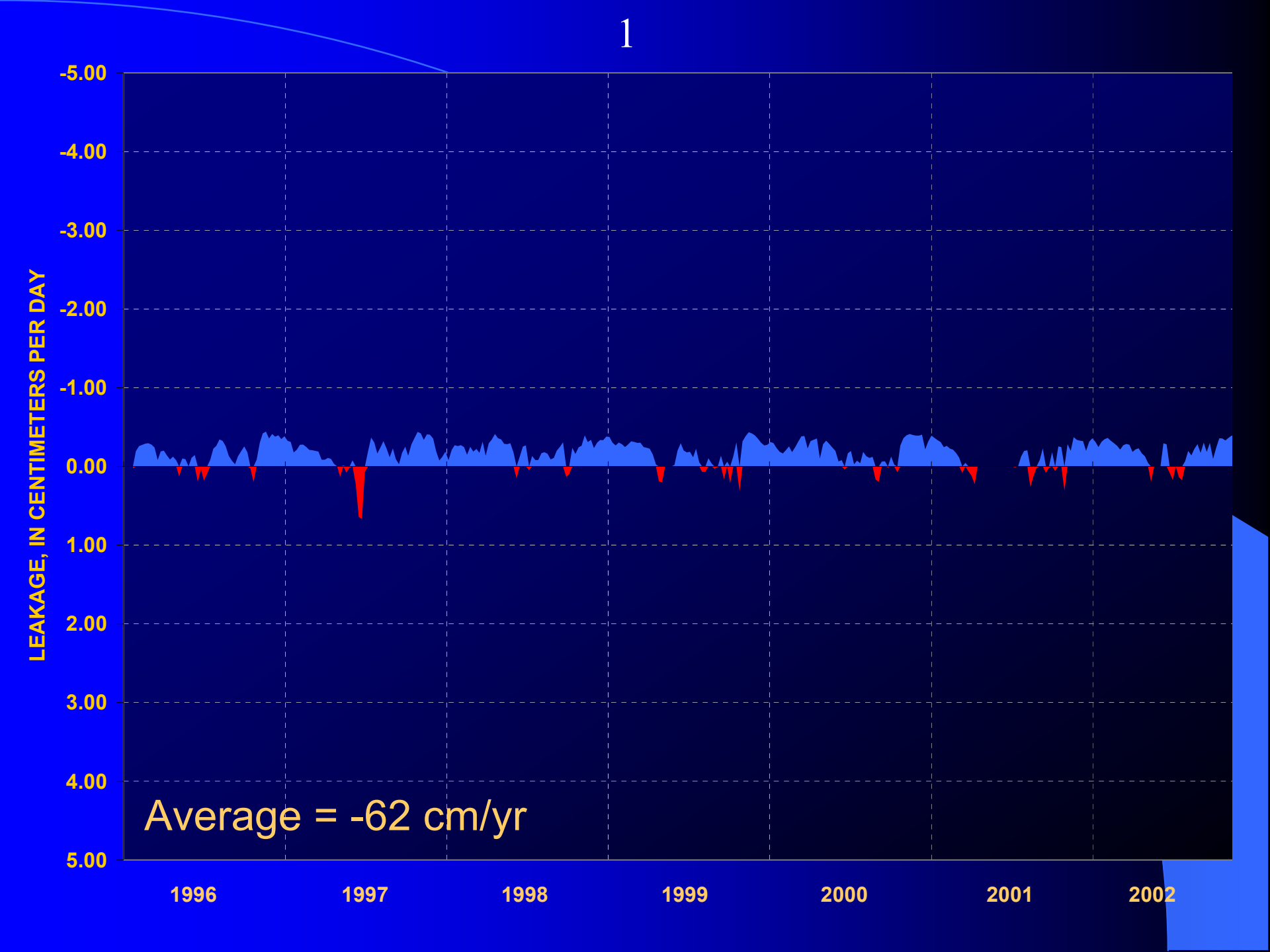


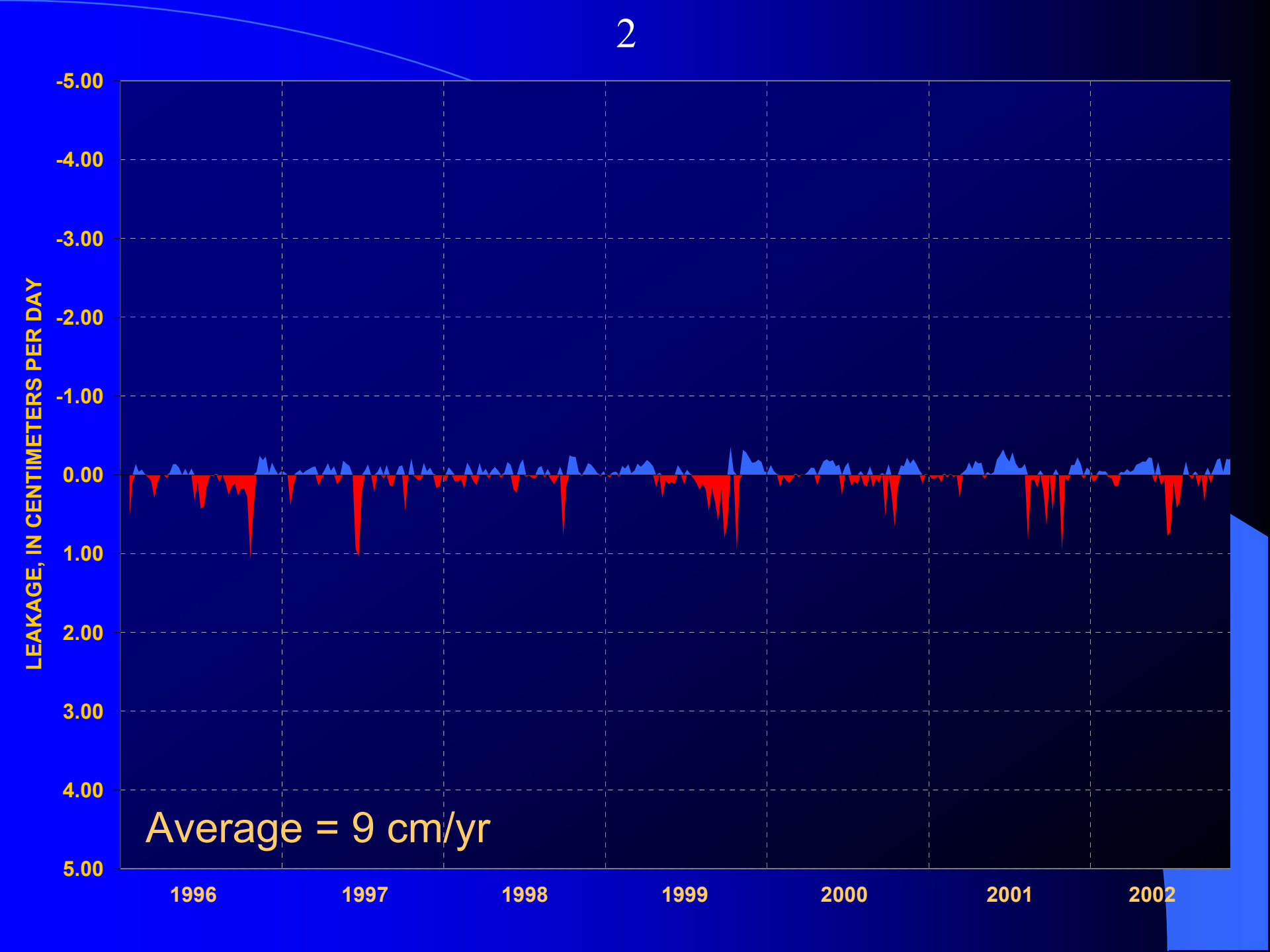
Wetland Stage at E146

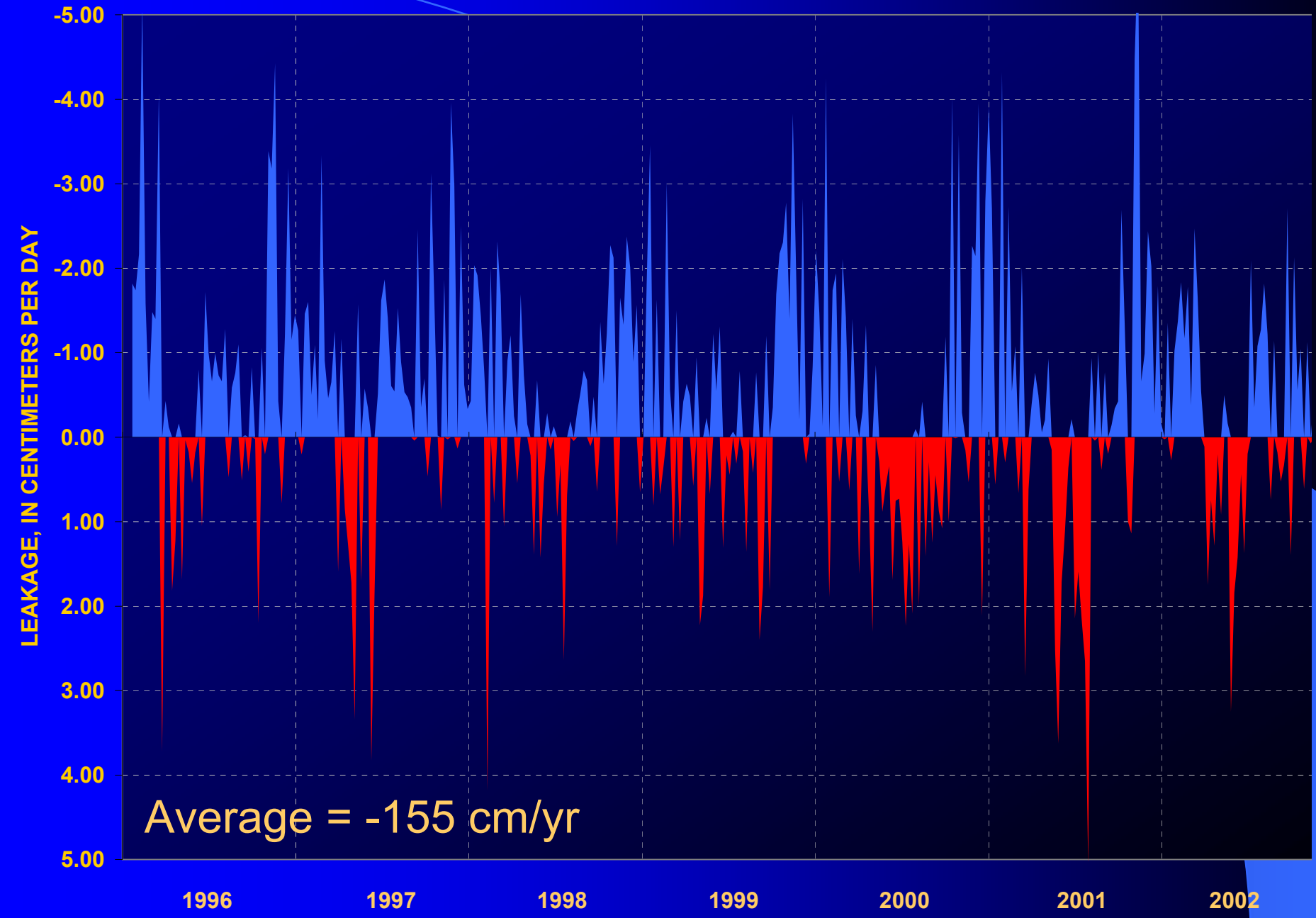


Surface Water/Ground Water Exchange

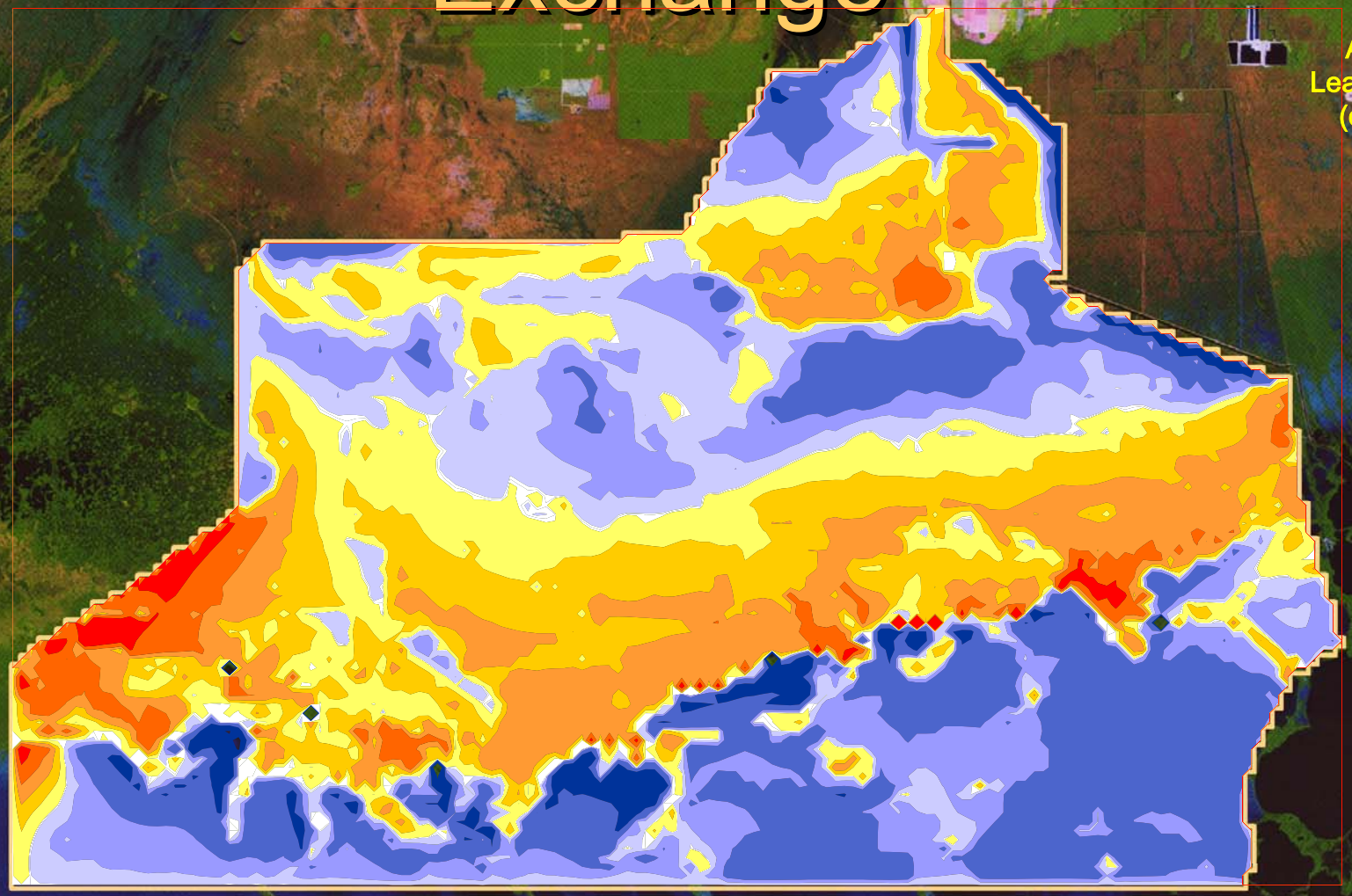



-5.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
5.00
LEAKAGE, IN CENTIMETERS PER DAY
1996
1997
1998
1999
2000
2001
2002
Average = -62 cm/yr

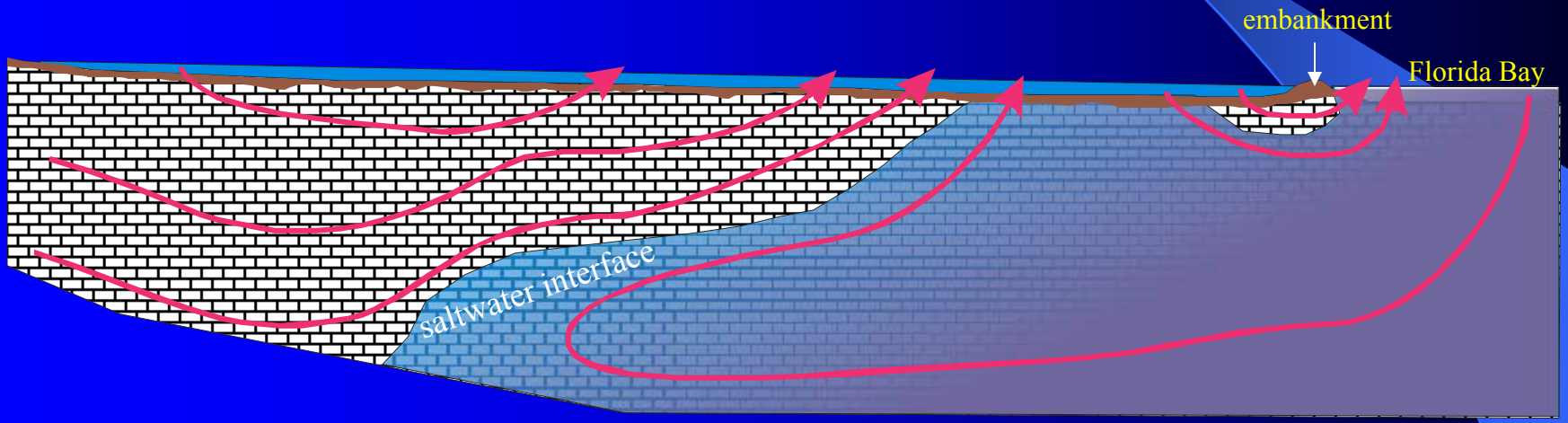

-5.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
5.00
LEAKAGE, IN CENTIMETERS PER DAY
1996
1997
1998
1999
2000
2001
2002
Average = 9 cm/yr


-5.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
5.00
LEAKAGE, IN CENTIMETERS PER DAY
Average = -155 cm/yr
1996
1997
1998
1999
2000
2001
2002

Surface Water/Ground Water Exchange



New Conceptual Model?



Summary and Conclusions

- SICS and TIME are designed to simulate the complex flow and transport patterns in the coastal interface between freshwater wetlands and marine estuaries
- SICS and TIME are developed using a wide range of hydrologic information
- The SICS model reasonably quantifies wetland hydroperiods, coastal interface salinities, and freshwater flows to Florida Bay

Future Plans

- Provide flows for Florida Bay/Florida Keys Feasibility Study (SICS and TIME)
- Water quality m
- Publish and doc